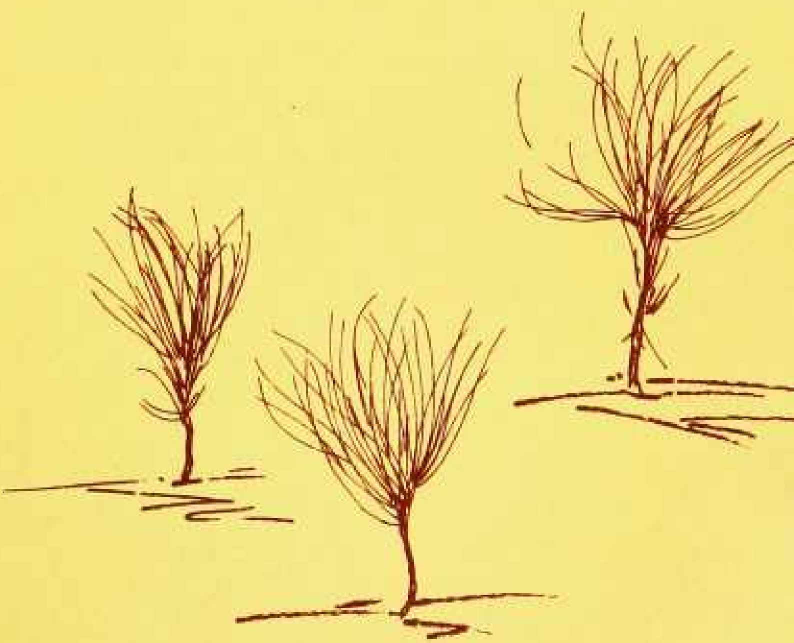
CONIFER NURSERY PRACTICE *in the* PRAIRIE-PLAINS



U.S. DEPARTMENT OF AGRICULTURE/FOREST SERVICE/AGRICULTURE HANDBOOK NO. 279

CONIFER NURSERY PRACTICE
in the
PRAIRIE-PLAINS

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ACKNOWLEDGMENT

Forest nursery practices for the Prairie-Plains have developed through research and the resourcefulness of nurserymen engaged in the production of planting stock. The 50 years of experience gained in conifer propagation at the Bessey Nursery in the Nebraska National Forest has provided the greatest single contribution to this handbook, and special gratitude is due M. K. Meines, the present superintendent. Other Federal nurseries supplying material were operated by the Soil Conservation Service, by the Prairie States Forestry Project (discontinued in 1942), and by the then Bureau of Plant Industry (now the Agricultural Research Service). Much assistance was received from State and commercial nurserymen, including Albert Engstrom, Norman, Okla.; John Molberg, Bottineau, N. Dak.; Lloyd Moffett and J. R. Weir, Fremont, Nebr.; and Clarence Jensen, Esmond, N. Dak.

CONTENTS

INTRODUCTION

The Prairie-Plains occupy a broad belt of highland between the Rocky Mountains and the Central Lowland. The region extends from San Antonio, Tex., to about Edmonton, Alberta, and Saskatoon, Saskatchewan. Included are the Great Plains proper, a region mostly west of 100° longitude with high altitude, semiarid climate, and short grass vegetation; and the prairie region, an area of tall grass bordering the eastern deciduous forest. In this essentially treeless area, farmers and ranchers need windbreaks to protect their buildings, livestock, and crops. Townspeople need trees along their streets and in their parks to beautify their cities and to provide shade.

Tree planting began in the Prairie-Plains just after the first settlers arrived. Many problems of tree establishment confronted the early planters. These included low annual precipitation, frequent high winds, unfavorable soils, and lack of knowledge concerning the adaptability of tree species to Plains conditions.

Over the years, from research and practical experience, many of the difficulties have been gradually overcome. For example, information is now available on what species to plant and how to plant and maintain the trees.

The growing success of tree planting has increased the demand for deciduous and coniferous planting stock. Meeting that demand will require the best nursery practice that experience and research can provide.

This manual summarizes available information on Plains conifer nursery practice and recommends to nurserymen specific methods for nursery stock production. It will supplement but not replace a bulletin published in 1941, "Nursery Practice for Trees and Shrubs Suitable for Planting on the Prairie Plains" (U.S. Dept. Agr. Misc. Pub. 434), a publication concerned primarily with deciduous stock production.

Some operations are fairly standardized, while others allow the nurseryman more choice of methods to fit his own situation. Both mechanized and hand methods required in producing trees are presented. Greatest emphasis is on methods suited to large-scale production. Manually operated devices, many developed by the large nurseries during mechanization, are described to meet the needs of small nurseries.

NATIVE CONIFERS

The natural stands of trees and shrubs in the Prairie-Plains are outliers of the Rocky Mountain forests on the west and of the Lake States, Central, and Southern forests on the east. Though their acreage, distribution, and number of species are not great, these stands have been important in reforestation in the Prairie-Plains because they have provided a source of seed from plants adapted for growing in this region.

Some conifers in the Prairie-Plains, such as ponderosa pine, eastern redcedar, and Rocky Mountain juniper, are distributed widely (fig. 1).[1] Others, such as pinyon, limber pine, lodgepole pine, white spruce, and blue spruce, have more limited distribution. Most of this natural growth is in breaks, bluffs, and escarpments of rough topography at the higher elevations of the western Great Plains (fig. 2). The localities of the most important species are described briefly below.

[1] For scientific names of trees and shrubs discussed, see Appendix.
Authority cited and dates enclosed in parentheses, as in the caption for figure 1, refer to items in Literature Cited, p. 81.

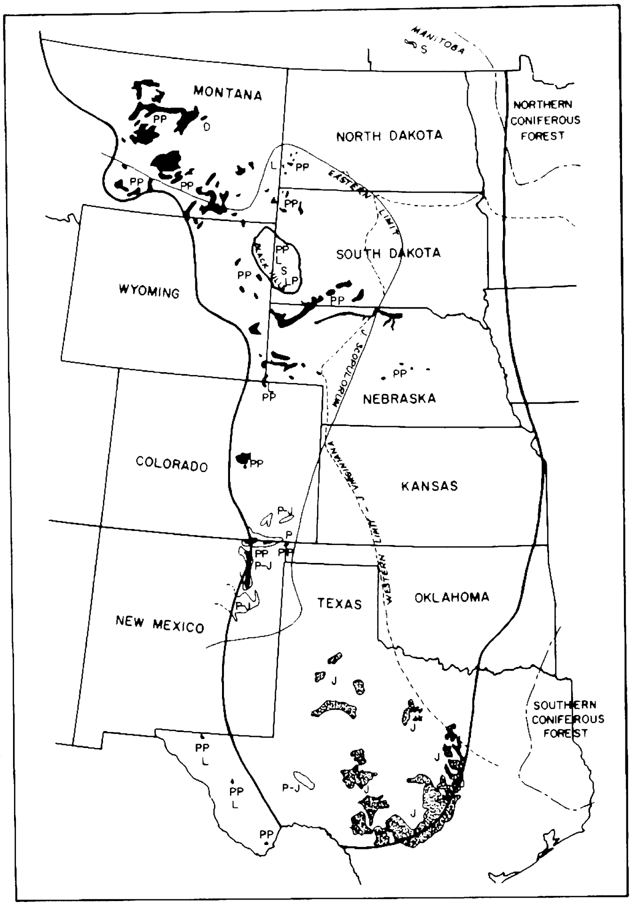

FIGURE 1.—Natural distribution of some important conifers in the Prairie-Plains. The approximate boundaries of the Prairie-Plains and the Black Hills are indicated by heavy black lines. The range of eastern redcedar (*Juniperus virginiana*) is shown by a dashed line and that of Rocky Mountain juniper (*J. scopulorum*) by a solid line. Detailed distributions are identified as follows: PP—ponderosa pine, L—limber pine, P—pinyon, LP—lodgepole pine, J—junipers other than those above, S—white spruce, and D—Douglas-fir. (Albertson 1940, Bray 1904, Cockerill et al. 1939, Curtis and Lynch 1957, Herman 1958, Hutchison and Kemp 1952, Livingston 1949, Nienstaedt 1957, Potter 1952, Stoeckeler 1952a, U.S. Forest Serv. South. Forest Expt. Sta. 1940, Ware 1936, Warner and Chase 1956, Williamson 1957, and Woodin and Lindsey 1954.)

Ponderosa pine.—Ponderosa pine is the most widely distributed of the pines. It is the main species of the Black Hills, and it is found in all of the Plains States but Kansas. At its easternmost extension in Nebraska, it appears in the canyons, on the rough stony land of the Pine Ridge escarpment, and in the Niobrara and Upper Platte River drainages. Isolated groves occurred as late as 1885 in the valleys of the Dismal, Calamus, North Loup, South Loup, Lodgepole, and Republican Rivers (Bessey 1895). In South Dakota, ponderosa pine is found in the Black Hills, in the northwest corner of the State in Harding County, and scattered over the hills of Shannon, Todd, Washabaugh, and Bennett Counties (Over 1932). It occurs in three southwestern North Dakota counties in the Badlands. In east-central Colorado, ponderosa pine extends eastward on the Platte-Arkansas Divide (Weaver and Albertson 1956). It also occurs associated with pinyon in the extreme northwest corner of Oklahoma.

Other pines.—Limber pine is found in southwestern North Dakota, the Black Hills of South Dakota, the extreme southwestern corner of Nebraska, southeastern Wyoming, and the adjoining portions of Colorado. Pinyon occurs in northeastern New Mexico, southeastern Colorado, and northwestern Oklahoma. Lodgepole pine is found very locally in the western part of the Black Hills and in the Cypress Hills of southwestern Saskatchewan.

Some Southeastern pines, while not found in the Prairie-Plains, grow on dry situations adjacent to the region. Included are shortleaf pine in eastern Oklahoma and eastern Texas, loblolly pine in a small area of southeastern Oklahoma and in eastern Texas, and longleaf pine in eastern Texas.

Junipers.—Eastern redcedar and Rocky Mountain juniper are the juniper tree species found most commonly in the Prairie-Plains. Both range from the southern limits of the Prairie-Plains into Montana and North Dakota in the north. Eastern redcedar predominates on the east and Rocky Mountain juniper on the west. The ranges of the two species overlap in central South Dakota and central and northwestern Nebraska. An area of natural hybridization has been delineated, but the degree to which this represents the overall situation is unknown (Fassett 1944). The two species may occur in stands together. In eastern Texas, eastern redcedar is found on dry, gravelly ridges and limestone hills (Jones et al. 1932). Other juniper tree species include one-seed juniper in western Texas, New Mexico, and extreme western Oklahoma (Little 1950); Pinchot juniper in central, northwestern, and Trans-Pecos Texas and in western Oklahoma (Jones et al. 1932); alligator juniper in Trans-Pecos Texas (Jones et al. 1932); and Ashe juniper in northeastern and southern Oklahoma and on the Edwards Plateau in central Texas (Hall 1952).

Spruce.—White spruce is generally found in the valleys of the Black Hills of South Dakota. Outliers also occur in south-central Manitoba and southwestern Saskatchewan. Blue spruce has been reported in the Big Horn Mountains in south-central Montana.

Douglas-fir.—Douglas-fir occurs on the Piney Buttes (Garfield County) in eastern Montana in an area where the mean annual precipitation is about 12 inches and minimum temperatures may drop to $-58°$ F. (Stoeckeler 1952a). Trees from this source have been used to a small extent in North Dakota plantings.

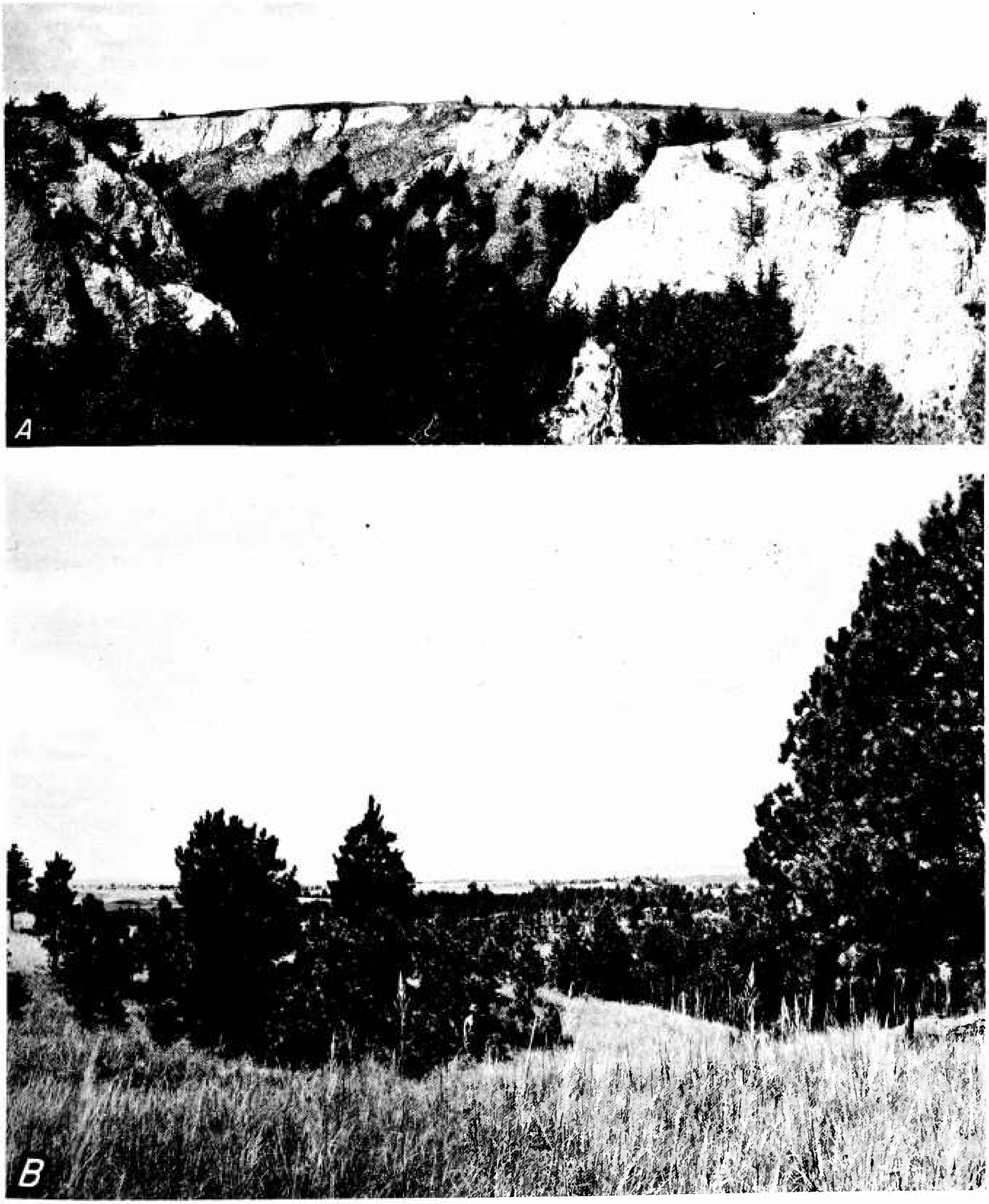

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FIGURE 2.—Natural stands of conifers in the Prairie-Plains: *A*, Eastern redcedar near Sargent, Nebr. (ponderosa pine and bur oak are associates); *B*, ponderosa pine in southwestern North Dakota on breaks of Little Missouri River. The pine has moved out into the grassland since fires have been controlled.

HISTORY OF CONIFER PLANTING

The planting of conifers for other than ornamental uses began many years ago in the Prairie-Plains. Block plantings of pine in Nebraska are recorded as early as 1873. According to the annual report of the then U.S. Division of Forestry, special efforts were made in 1898 to introduce conifers into existing plantings. Conifer nurseries had been established at several locations, and in 1898, 300,000 conifers had been distributed to farmers in quantities sufficient for 1- to 5-acre plantations. Despite these early efforts, few of the conifer plantings established before 1935 are extensive enough to allow planters to compare their performance with that of hardwoods in protection plantings. Coverage of the Plains was incomplete, and some species had little representation in some localities. A notable exception is block plantings of conifers started in 1904 on the Nebraska National Forest in the sandhills region (fig. 3).

Conifers were planted over a wide area of the Prairie-Plains by the Prairie States Forestry Project. Included in the 18,600 miles of shelterbelts planted between 1935 and 1942 under a great variety of climatic and soil conditions, these trees have been one of the main sources of information on the performance of various evergreen species in the Plains. An appraisal made in 1954 (Read 1958) of 938 shelterbelts from North Dakota to northern Texas showed that conifers, when once established, survived well throughout the survey area. Eastern redcedar was the hardiest tree. Ponderosa pine and Austrian pine showed good drought resistance and staying power despite initial survivals of less than 50 percent. Other species used by the Project were Rocky Mountain juniper, alone and with eastern redcedar, from North Dakota to Oklahoma; blue spruce and white spruce in the Dakotas; and jack pine and Scotch pine in South Dakota, Nebraska, and Kansas. Shortleaf and loblolly pines were used in the plantings of southern Kansas, Oklahoma, and Texas.

Austrian and Scotch pine have been widely planted in the Prairie-Plains. Austrian pine grows slower than ponderosa pine in Texas (Jones et al. 1932) and in Oklahoma (Afanasiev 1949a). It has been difficult to establish in North Dakota. Scotch pine has exhibited early rapid growth but is short lived and is more subject to mortality by drought.

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FIGURE 3.—This forest plantation of jack pine in the sandhills of the Nebraska National Forest was large enough by 1940 to produce posts and small poles.

Shortleaf pine has been planted in windbreaks in western Oklahoma (Afanasiev 1949b). Some loblolly pine, Japanese red pine, and Japanese black pine are used in eastern Oklahoma. Japanese black pine has been a fast grower, faster than all pines but shortleaf pine, and has a low susceptibility to tip moth damage. Japanese red pine has poor form, with multiple stems, and is highly susceptible to tip moth damage. Jack pine and eastern redcedar have been planted extensively and quite successfully in Nebraska, particularly in block plantings in the sandhill region.

Arizona cypress, a native of western Texas, New Mexico, and Arizona, has been used with great success in Texas and Oklahoma for windbreak and ornamental plantings. Trees of this species are tender while young but have withstood temperatures as cold as 10° F. when older (Jones et al. 1932). The form from central Arizona, called smooth Arizona cypress and characterized by smooth outer bark, is widely cultivated in warm, dry regions in shelterbelts and as an ornamental; it also is used for Christmas trees and fenceposts (Little 1950). Selections of oriental arborvitae are easy to establish and grow fairly fast. They have proved very hardy and effective in windbreak plantings.

FUTURE OF CONIFER PLANTING

More hardwoods than conifers have been planted in the Prairie-Plains. This was only natural. The Prairie-Plains had little native coniferous growth. Because hardwood planting stock was more available to planters and grew faster, it appealed more to the homesteader intent on securing some early protection for his farmstead. Bare-rooted conifers often dried up during transportation, and the rigorous climate limited their establishment after planting.

However, in the future, conifers will have an increasingly important place in Plains planting programs. Among their inherent advantages over most hardwoods are year-round foliage retention, greater longevity, lower fertility and soil moisture requirements, relatively more freedom from insects and diseases, and the ability after establishment to compete more successfully with weeds and grasses. Conifer needles remain under the trees, building up a vegetation-smothering and soil-protecting layer of litter that also increases water infiltration and reduces moisture evaporation. In a study of tree planting on the drier sections of the northern Great Plains, it was found that the coniferous species do not exhaust the soil moisture to as great a depth as do the hardwoods, and that they establish forest conditions very readily in reasonably full stands (George 1939).

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FIGURE 4.—Use of conifers in windbreak plantings on the Prairie-Plains: *A*, An 18-year-old planting of shortleaf pine in a field shelterbelt near Vernon, Tex.; *B*, right-angle view of a dense single-row planting of eastern redcedar, 15 years old and 18 feet high; *C*, effective year-round wind protection is provided by 25-year-old ponderosa pine in field windbreak near Towner, N. Dak.

Conifers are well adapted for all protection plantings, whether they be for farmstead, field, livestock, wildlife, or for multiple purposes (fig. 4). Not only do they provide year-round protection, but their thick crowns trap snow, and the trees offer less competition to adjacent crops (Greb and Black 1961). The soft wood has more value at maturity and is more easily disposed of than the wood of deciduous trees. Conifers are also particularly suited for ornamental plantings and for use as Christmas trees.

Conifers, of course, have some disadvantages when compared to hardwoods. It takes longer and costs more to produce planting stock. The trees are harder to establish, and because initial survivals in the field are lower, more replacements are required. Because they have a slower initial growth and consequently must compete with grass and other ground cover for a longer period, more maintenance is needed. Retention of the foliage throughout the year subjects the trees to excessive drying during periods of near dormancy. Damaging agents, such as fire or livestock, will reduce growth and may eliminate the trees since most conifers are unable to sprout or restore foliage. Reproduction of conifers other than eastern redcedar rarely occurs in farm plantings. Finally, adapted seed from natural or planted stands has been hard to obtain in quantities large enough to handle economically.

Nevertheless, the advantages far outweigh the disadvantages. Furthermore, some of the obstacles can be overcome. In the drier portions of the Plains the use of potted trees and more careful handling of barerooted stock from the time of lifting in the nursery to planting have resulted in higher initial survivals. Improved machines and methods of tillage have increased both initial survival and growth rates. Increased use of trees grown from seed of established plantings and of native stands of proven hardiness should also provide trees that survive better and grow faster.

COLLECTION AND HANDLING OF SEED

IMPORTANCE OF SEED SOURCE

There is abundant evidence that conifer seed from local sources produces planting stock more resistant than imported stock to loss from drought, insects, and disease. Foresters and others engaged in tree planting in the Prairie-Plains generally agree on the importance of using seed sources adapted to local climate and soil conditions. However, this requisite too often is slighted or ignored. Since the advent of large-scale tree planting on the Plains, a large number of trees of unsuitable origin have failed or have grown poorly. Thus, much of the effort spent in seed collection, production of nursery stock, and establishment in the field has been wasted.

Though seed source research has been less extensive in the Prairie-Plains than in many other areas, there are some specific examples of seed source variation for conifer species grown in the Plains. In a study of the survival and growth of 25- to 41-year-old trees of six Scotch pine races under prairie conditions in Saskatchewan, differences were apparent and seemingly distinctly inherent (Cram and Brack 1953). Investigators have reported that the growth and survival of ponderosa pine is influenced by racial origin; they found wide variations in height growth and survival between lots of wide geographic origin and altitudinal zones (Bates 1927, Callaham and Metcalf 1959, Munger 1941, Weidman 1939). In the sandhills of Nebraska, planted ponderosa pine of Nebraska origin were less damaged by tip moth than were the trees of New Mexico seed source (Bates 1927). There was also variation among lots in browsing by deer.

The variability in hardiness of ponderosa pine grown from seed originating in different climates was evident in 6-year-old plantings in McHenry County, N. Dak. In March 1946, severe winter injury appeared as the pine underwent browning and defoliation. The heaviest damage was sustained by trees with Black Hills and western Nebraska origins, and the least by trees grown from seed of the nearest native origins (western North Dakota and eastern Montana). Again, following the winter of 1947–48, the trees of the near-local sources showed less foliage injury (Stoeckeler and Rudolf 1949).

Outstanding performances of the local sources have been observed many times at the Bessey Nursery, Halsey, Nebr. Scotch pine from a local collection produced 2–0 seedlings nearly twice as large as those from a central European source. Austrian pine from seed collected near Lincoln, Nebr., produced stock far more satisfactory than any Austrian pine previously grown. In 1955, it was noted that 2–0 ponderosa pine beds varied considerably by seed origin; the best lot was from a local collection.

The Nebraska National Forest, with 30,000 acres of conifer plantings established from 1903 to 1958, is an outstanding example of a site on which seed of local origin was used. The first trees planted were wildlings shipped in from the Black Hills and the Lake States, but the establishment of a nursery in 1902 soon made it possible to control the source of stock. In the spring of 1904, 1–0 ponderosa pine, grown from seed collected in 1902 in northwestern Nebraska, was planted. The first eastern redcedar seed used was collected in 1912 in a natural stand along the Niobrara River. In the early 1920's, seed of Austrian and Scotch pine was collected from ornamental and shelterbelt trees in eastern Nebraska to supplement seed purchased from Europe. These local plantings have demonstrated reasonably good adaptation to local conditions.

European countries have much broader experience than the United States in the harmful effects of indiscriminate use of seed without regard to origin. Some of them have passed strict laws providing for the certification of the source of seed. There are no Federal or State laws in the Plains States requiring the use of forest tree and shrub seeds of known origins. However, certification of tree seed is now possible in South Dakota under State laws pertaining to cereal, forage, and oil crops. The International Crop Improvement Association approved minimum standards for tree seeds in 1959 and adopted more widely applicable standards in 1962 (SAF Seed Certification Subcommittee 1963).

In 1939 the U.S. Department of Agriculture adopted a seed policy that partly requires and partly recommends use of local or well-adapted seed for forestry and related purposes. It requires tree planting agencies in the Department to use in their planting programs, wherever practicable, seed of known origin from within 100 miles distance and 1,000 feet elevation of the planting site. It recommends keeping an accurate record of such seed, including the lot number, year of seed crop, species, origin as to State, county, and specific locality, range of elevation, and proof of origin. (See Appendix for entire policy statement.)

A suggested minimum program for collecting seed in the Prairie-Plains included the following points (Engstrom and Stoeckeler 1941):

1. Zone the seed collection area according to climate.
2. Limit collection largely to local seed.
3. Pick seed only from healthy and vigorous trees of reasonably good form.
4. Keep an accurate, permanent record of seed source from time of collection through field planting, including proper identification and labeling of the seed and the place and elevation of collection.
5. Import seed only after giving thorough study to the experience with seed from different foreign countries.

SEED COLLECTION ZONES AND LOCALITIES

Eleven seed collection zones, based primarily on latitude, have been delineated for the Prairie-Plains (fig. 5). It is recommended that seed be collected and the progeny planted within the same zone. Where absolutely necessary it is permissible to move seed or stock from one zone to an adjoining zone. Compensating factors such as elevation would permit movement of seed northward across one or two States. Thus, blue spruce seed can be moved safely from the higher western part of the more southern seed zones in Colorado and Wyoming to northern North Dakota (Engstrom and Stoeckeler 1941). A little movement to the north may result in reasonably hardy trees that grow slightly faster than trees of local origin. These zones were based on observation and experience and proved workable in the Prairie States Forestry Project. It is recommended that they be used until research discloses a better basis for zonation.

Trees from northern seed planted farther south generally survive fairly well; however, they may grow slowly, develop poorly, and eventually succumb to drought and heat. If the northern stock buds out on the first warm days of spring, the new growth may be damaged by frost. When trees grown from southern seed are used too far north, they may soon die because they lack the hardiness and early ripening of wood necessary to withstand the northern winters (Engstrom and Stoeckeler 1941).

Movements from east to west—that is, generally to drier climates—appear less harmful than latitudinal movements but should not be encouraged (Engstrom and Stoeckeler 1941).

Although the seed collection zones shown in figure 5 are generally applicable to most conifer species in the Prairie-Plains, more specific localities can be given for collecting seed of a few species in certain areas. Ponderosa pine seed should be collected from the more arid portions of its range bordering the Plains. Good

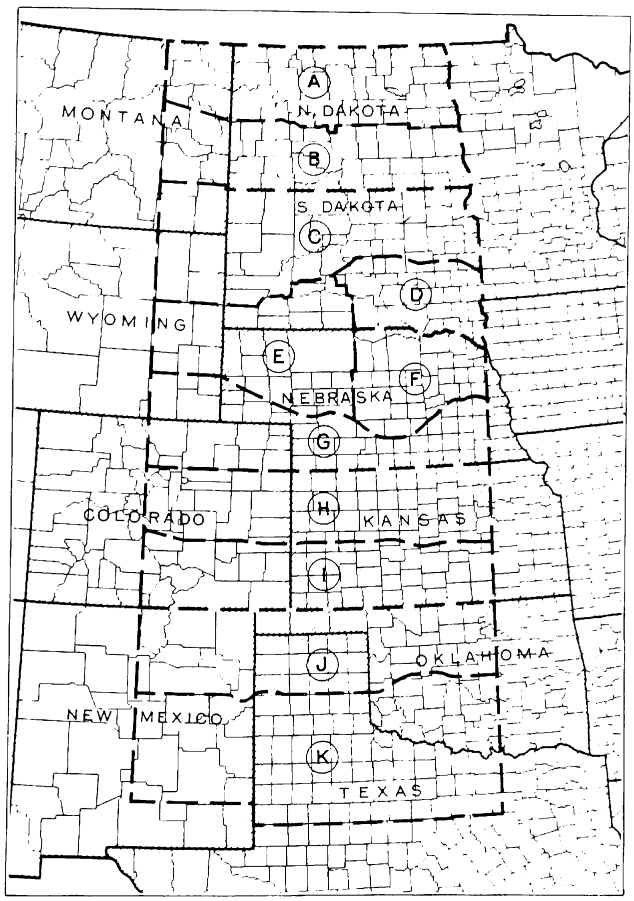

FIGURE 5.—Seed collection zone map for the Prairie-Plains. Broken lines separate the zones (Engstrom and Stoeckeler 1941).

sources in Nebraska are the Pine Ridge and Niobrara River areas; in South Dakota, the northwest and on the Rosebud and Pine Ridge Indian Reservations in the southwest; in North Dakota, the southwest; and in Montana, the extreme east. Seed from the foothills of the Black Hills has been used rather extensively because the quantity of seed produced is greater and more reliable than in other collection areas. Further study will be needed before this source can be fully evaluated, but it seems likely that at least some Black Hills seed can be used with confidence in Nebraska and to the north. Eastern Colorado sources seem best for use in Kansas and to the south.

Seed collections of Rocky Mountain juniper and eastern redcedar should be made as near the latitude of the planting site as practicable.

Rocky Mountain juniper should be collected in North Dakota along the Little Missouri River near Medora, in northwestern South Dakota, and in extreme eastern Montana.

Seed of eastern redcedar should be collected in South Dakota from the bluffs of the Cheyenne River and from other native stands. However, seed collected along the Platte River in Nebraska does reasonably well in South Dakota (Hansen 1930). In Nebraska, eastern redcedar sources in and adjacent to Custer, Loup, Blaine, and Brown Counties have produced stock better suited to statewide planting than seedlings of Platte Valley origin. Collections of redcedar along the Cimarron River have proved well adapted to Oklahoma planting sites.

In the prairie provinces of Canada, spruce seed collected from older specimens in windbreaks of the nurseries at Indian Head and Sutherland and from natural stands in Manitoba and northern Saskatchewan have produced stock adapted to Canadian conditions (Ross 1937). Generally, common commercial seed has not proved hardy.

SELECTION OF INDIVIDUAL STANDS AND TREES

Next in importance to using seed from local sources is collection from selected stands and individual trees with desirable characteristics. Tree improvement studies of forest trees have revealed wide variations between individuals of the same species (fig. 6). Superior trees with desirable characteristics should be noted, and their location should be recorded.

Some traits of value in windbreak and shelterbelt trees are tolerance of drought conditions, ability to grow on alkaline soils, and resistance to snow, wind, and glaze injury (Rudolf 1956). Other desirable characteristics are compactness, resistance to insects and disease, and rapid growth without spindliness.

Trees and stands that are superior in growth characteristics should be used for seed collection as much as possible. Cones obtained from squirrel caches may be of good genetic character only if the stand as a whole is composed of trees of good form.

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FIGURE 6.—A row of 21-year-old ponderosa pine in the North Dakota State Nursery at Towner, McHenry County, N. Dak. The differences in height growth, broadness of crown, density of foliage, and angle of branching illustrate the wide variation between individuals of the same seed source.

If block plantings are being considered for wood production, the form and height of the parent tree and quality of the product must also be considered. Lumber from ponderosa pine growing on the hills along the Little Missouri River northwest of Amidon, N. Dak., reportedly was brash and inferior to lumber cut from trees about 35 miles distant in the Long Pines or Ekalaka Divisions of the Custer National Forest in Montana. Of course, it is not known whether these differences stem chiefly from genetic or acquired characteristics.

Seed orchards should also be established from the material of carefully selected stands. Seed orchards of hardy and desirable form of oriental arborvitae and Arizona cypress have been established in Oklahoma.[2] Similar developments are likely to be planted in other Prairie-Plains States.

DETERMINATION OF SEED RIPENESS AND QUALITY

The soundness of seeds by locality or even by plant should be tested before extensive collecting is done. Seed viability may vary considerably among stands and trees. Seeds from each tree can be tested quickly by cutting them open with a small wire nipper and seeing whether they are filled. This practice, carefully followed, will eliminate trees with many weeviled and hollow seeds before considerable labor and money are expended.

[2] Personal communication with E. W. Johnson, Agricultural Research Service Field Station, Woodward, Okla.

The ripeness of seed must also be judged during collection, since immature seed does not keep as well as ripe seed in storage and is of lower germination capacity (Engstrom and Stoeckeler 1941). Seedlings from immature seeds are smaller and less vigorous than those from mature seeds (Toumey and Korstian 1942). Cutting tests are also recommended to estimate seed maturity. The kernel of a mature seed is firm and white or cream colored, and fills the cavity completely.

Ripening dates of a species vary by season or locality because of local climate. Therefore, frequent inspections may be required to determine in advance the approximate ripening dates. Failure to closely observe the progress of ripening for species that hold their seed for only a few days after maturity, such as limber pine and oriental arborvitae, may result in loss of the crop.

The seed of Rocky Mountain juniper takes 2 years to mature. One-year fruit is light green as compared to the light blue of the mature fruit. It should not be collected since the green and mature berries are hard to separate. No collections should be made from trees with large amounts of green berries.

In Nebraska, under dry conditions, ponderosa pine cones can usually be collected directly from the trees only during the 2 to 3 weeks between the time proper ripeness is reached and the opening of cones on the trees. The seed of Austrian pine ripens 2 weeks later than that of ponderosa pine; the cones remain closed longer, sometimes through the winter.[3]

Ponderosa pine cones are ripe enough to collect when their specific gravity in place on the tree has dropped to 0.85, or when a majority of five sound, freshly picked cones will float in kerosene. The time of squirrel collection is not a reliable index of seed ripeness since they often cut the cones 3 to 4 weeks in advance of seed maturity. Color also is not a reliable index of cone ripeness (Maki 1940).

Spruce cones are ripe enough to collect when the seed coats darken and the kernels become firm (U.S. Forest Serv. 1948). In a study of seed maturity of planted spruce in Saskatchewan, it was recommended that collection of blue spruce cones be delayed until 90 percent or more freshly picked cones float in linseed oil, which has a specific gravity of 0.94 (Cram 1956a). For white spruce, collection is recommended when 90 percent or more freshly picked cones float in turpentine (Cram 1957).

The berries of eastern redcedar, Rocky Mountain juniper, and oldfield common juniper are dark blue when ripe. However, they are usually coated with a powdery bloom; therefore, they appear light blue.

For a further discussion on the seed ripening process and the time to collect, refer to the "Woody-Plant Seed Manual" (U.S. Forest Serv. 1948).

[3] Personal communication with M. K. Meines, Superintendent, Bessey Nursery, Halsey, Nebr.

SEED CROP FREQUENCY

The size of seed crops will vary from year to year, depending on several factors. Among the most important are the climatic conditions during flowering, seed formation, and ripening; the damaging effect of insects and rodents; the age of the seed trees; the size of the flower crops; and the inherent ability of the tree or species to produce seed. Seed may be destroyed by insects that attack the buds, flowers, and immature cones, as well as the seed itself (Lanquist 1946). Seed production by eastern redcedar is often reduced by late spring frosts which damage the female flowers.

No periodicity in seed crops has been noted in ponderosa pine (Curtis and Lynch 1957). Observations over 23 years east of the Continental Divide in Montana showed this species to be a poor seeder—only one good seed crop occurred (Boe 1954). Two good crops, two fair ones, and five failures were recorded during a 9-year period in the foothills of the Rockies in eastern Colorado (Roeser 1941).

Junipers produce more good seed crops. Particularly heavy crops of Rocky Mountain juniper seed are produced every 2 to 5 years, and some seed is borne nearly every year (Sudworth 1915). Eastern redcedar produces good crops every 2 to 3 years in Oklahoma (Afanasiev and Cress 1942a). The same frequency of good seed years occurs at Halsey, Nebr., where nine good seed crops of eastern redcedar were recorded in windbreak plantings between 1929 and 1956. Seed production of trees in windbreak plantings may differ from that of trees in wild stands because of dissimilar growing conditions and parentage.

Availability of seed in the quantities necessary to fill nursery seeding and planting quotas must also be considered along with the climatic adaptability of any source or "strain." Some species set a good crop of cones at infrequent intervals. Usually some seed is produced in other years, but it is generally scattered and is often so poor that the cost of a pound averaging 50 percent or more in germination may be three or four times as high as seed collected in a good seed year.

Since most seed retains its viability well when stored properly, it is good to provide for the future in years when a good supply of high-quality seed is obtainable.

SEED YIELDS

Complete records on seed yields of species commonly used in Prairie-Plains tree planting are available in the "Woody-Plant Seed Manual" (U.S. Forest Serv. 1948). However, localized information on yields is desirable since some widely used species have extensive ranges outside the Plains.

Data on the seed yield of ponderosa pine, eastern redcedar, and Rocky Mountain juniper in native stands of the Great Plains were obtained primarily from the Bessey Nursery records, which cover a period of more than 50 years (tables 1 and 2). Collections were made in most years. The range in yields is perhaps wider than would normally be expected, and resulted indirectly from the policy of the Nebraska

TABLE 1.—*Ponderosa pine: yield of freshly collected, cleaned seed in native stands of the Great Plains*

Locality	Collections	Yield per bushel of cones		Seed per pound		
		Average	Range	Low	High	Average
	Number	*Ounces*	*Ounces*	*Number*	*Number*	*Number*
Nebraska [1]	7	20	13–36	8, 200	11, 500	9, 700
Black Hills	3	20	18–22	13, 400	16, 600	14, 600
Eastern Montana [2]	6	(3)	(3)	12, 600	19, 300	15, 700

[1] Seed from stands along the Niobrara River at Pine Canyon in Custer County and from one collection on the Rosebud Indian Reservation in South Dakota.

[2] From collections at Fallon, Glendive, and Jordan, Mont.

[3] Data not available.

National Forest of collecting as much seed locally as was possible. Also, the berries or cones occasionally yielded little viable seed, owing to insect infestations or other causes.

The yield of ponderosa pine varies from 13 to 36 ounces per bushel for Nebraska cones, and from 18 to 22 ounces for cones from the Black Hills (table 1). Average yields, 20 ounces per bushel of cones, are about the same for the two sources.

The low yields of eastern redcedar in Nebraska represent collections in years when the seed crop was poor and insect infested (table 2). The larger yields are for good to excellent seed years.

Now that many planted stands are bearing seed, the nurseryman has a much wider selection of parent trees from which to collect. Seed collection from mature stands or from those of known seed origin is preferable.

Redcedar berries have been collected for many years from a windbreak 60 years old at Anselmo, Nebr. The trees are probably of natural origin and have produced as much as 80 pounds of berries per tree. At Anselmo an experienced man can pick an average of 40 pounds of berries per day in years of good to excellent crops.

Few records are available for seed production in planted stands of conifers in the Plains, but there is a partial record for such stands on the Nebraska National Forest (table 3).

This record indicated that planted stands will yield good seed in economical quantities whether they be in block plantings or in individual rows of shelterbelts. The yield of ponderosa pine seed in plantations at Halsey, Nebr., an average of 20 ounces per bushel of cones, compared very well with that of native stands. Austrian, Scotch, and jack pine from local sources provided a supply of good-quality seed from acclimated trees. The seed tended to be larger than that obtained from the native sources of the three species. Some seed was produced on Scotch and jack pine trees less than 20 years old, but substantial quantities were not produced from Scotch, Austrian, and ponderosa pine until they were 25 to 30 years old. In Oklahoma, Johnson[4] noted that Austrian pine does not produce much seed before the trees are 20 years old.

The number of seed per pound also varies consid-

[4] Personal communication with E. W. Johnson, Agricultural Research Service Field Station, Woodward, Okla.

TABLE 2.—*Juniperus: yield of newly collected, cleaned seed in natural and planted stands*

Species and locality	Collections	Yield per 100 pounds of berries		Seed per pound		
		Average	Range	Low	High	Average
Eastern redcedar:	*Number*	*Pounds*	*Pounds*	*Number*	*Number*	*Number*
Nebraska, planted [1]	20	15. 3	4–20	37, 200	55, 000	43, 200
Nebraska, natural stands [2]	9	16. 2	3–18	37, 000	53, 300	42, 800
South Dakota, natural stands	3	17. 5	14–19	42, 200	46, 100	43, 400
Oklahoma, natural stands	(3)	14. 0	7–16	(3)	(3)	(3)
Rocky Mountain juniper:						
South Dakota, Nebraska, Wyoming, and Montana natural stands. [4]	12	19. 8	11–28	22, 000	32, 000	27, 200

[1] Planted windbreaks at Anselmo and Halsey. Yields based on 27,000 pounds of berries.

[2] Yields based on 9,439 pounds of berries.

[3] Data not available.

[4] Yields based on 3,637 pounds of berries.

TABLE 3.—*Pinus: yield of newly collected, cleaned seed in planted stands, Nebraska National Forest*

Species	Collections	Yield per bushel of cones	Seed per pound		
			Low	High	Average
	Number	*Ounces*	*Number*	*Number*	*Number*
Ponderosa pine	2	23–24	10, 200	12, 200	11, 200
Austrian pine [1]	8	6–15	14, 000	22, 800	18, 500
Scotch pine	3	6–12	42, 200	57, 100	48, 100
Jack pine	5	6–13	74, 100	85, 300	79, 100

[1] Seed from stands near Lincoln, York, and Oakland, Nebr., averaged 20,300 per pound.

erably, depending on the locality of the collection, season, and degree of dryness. Fresh seed tends to be heavier than seed that has been stored over a period of years, so averages are given for newly collected seed.

Conifers are sometimes depredated by cone- and seed-eating insects. The cone moth *Dioryctria auranticella* (Grote) was noted at Halsey in 1928, about the time when ponderosa pines were first starting to bear cones. This insect is common in native ponderosa pine stands in adjacent areas of Nebraska and South Dakota. Blue spruce cones have been damaged in southern Saskatchewan by the spruce coneworm (*D. reniculella*) (Grote) and those of white spruce by the spruce seedmoth *Laspeyresia youngana* (Kft.) (Peterson and Worden 1959). Other insect enemies undoubtedly are also present.

METHODS OF SEED COLLECTION

Seed collection in the Plains often involves much travel over widely scattered areas and use of special collecting equipment. The equipment necessary for efficient seed collection varies by species. However, nursery labor and equipment can be used to make local seed collections of some species. For a season's work on various species, collection crews should be equipped with wire nippers or side cutters for field cutting tests and other purposes, cutting hooks for detaching cones (fig. 7), ladders, picking bags, baskets, sacks, tags, twine, ropes, linemen's safety belts, goggles, hardhats, heavy leather gloves, and tarpaulins or seed sheets.

A nursery practice handbook, based on many years of experience at the Bessey Nursey, contains the following suggestions for seed collection in planted and natural stands of conifers.

Purchased seed should be obtained from a reliable collector or seed dealer who will guarantee the collection area and year of collection (see "Where to Purchase Seed," in appendix).

The foremen define the seed collecting areas and select individual trees desirable as to age, tree form, and other characteristics. Pickers work in pairs to facilitate the movement of the ladders and other equipment from tree to tree. Man-day production is greater when trees of low yield are bypassed. Collection methods to be used depend on the characteristics of each species.

Because they are borne mostly on the branch tips, ponderosa pine cones can be picked more efficiently from ladders than by climbing the trees. For safety, pickers should carry a short rope on the top rung of

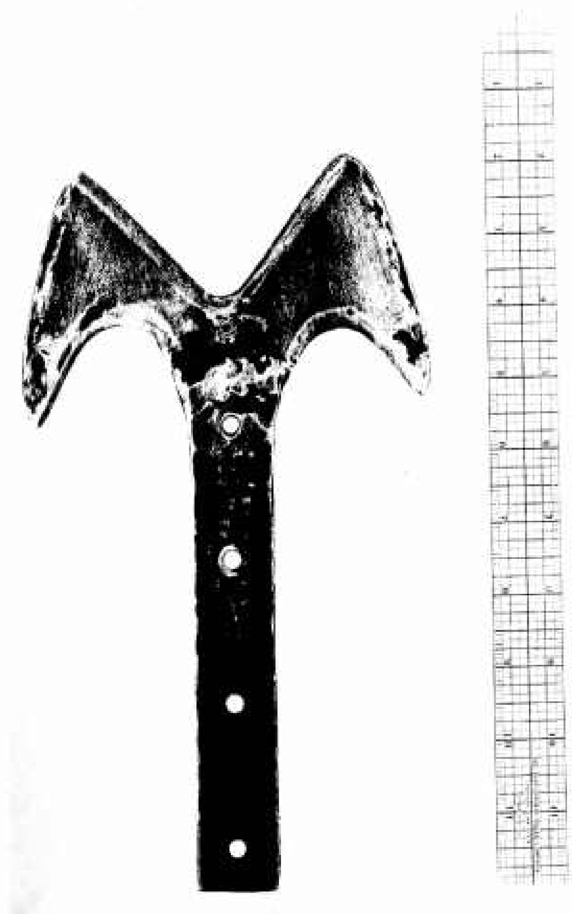

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FIGURE 7.—A cutting hook for detaching fruit, cones, or small limbs from trees; it is made from two mower blades welded to a flat piece of steel 8½ inches long.

the ladder and tie the ladder to a stout branch or to the tree bole. Cone hooks are used to bring cone-laden branches toward the picker and to cut loose cones beyond arm reach. The cones usually are dropped and picked up later. In the well-stocked stands of the Black Hills, ponderosa pine cone collections can be made from squirrel hoards.

Austrian pines are easier to climb than ponderosa pines, and the cones come off easier. Serotinous jack pine cones have been collected from branches removed during pruning and thinning. Limber pine tends to open its cones rapidly, and the wingless seed may fall to the ground. However, the seed will remain in the open cone on the tree for a few days if there is no wind, and much of it can be saved by spreading tarpaulins under the tree before the cones are picked. When the picker is working on the ground or on low ladders, the cones are put in a sack worn around the neck.

Juniper berries are collected on the Nebraska Forest by stripping them directly into picking bags or baskets strapped to pickers, by rubbing or stripping them into tarpaulins spread under the trees (fig. 8), or by a combination of these methods. The branch is taken between the hands, and near its end it is rubbed with a rolling motion. Part of the debris can be removed while the fruit is still on the tarpaulins by shaking them to bring the coarse material to the surface.

An alternate method, one of those used in cold weather, is to beat the frozen berries from the branches with a stick 12 to 18 inches long and 1 to 2 inches thick. The end of the stick is padded with several layers of burlap.

Quite often more than half the tree seed can be reached from the ground, and the rest can be gathered from short ladders. If the crop is good, the tree need not be picked clean. When good seed trees are few, the older and taller trees may furnish most of the good seed, and taller ladders are needed.

Tarpaulins are not used in brushy areas or on steep slopes. Here, bags with open-hooped mouths are hung from the neck. The use of strippers mounted on poles has damaged trees and resulted in an accumulation of much trash among the seed.

F-334697

FIGURE 8.—Collecting eastern redcedar berries from native trees in the Platte River Valley near Fremont, Nebr.

The seed of oriental arborvitae and some Arizona cypress is obtained from planted trees. The seed of oriental arborvitae must be picked promptly when the cones begin to open and before the small seed falls to the ground. The cones of Arizona cypress remain closed on the tree, permitting a longer period for collection.

CARE OF FRESH SEED

Seeds of most conifers are not dry enough to be stored immediately after collection. They must receive adequate aeration or be placed in a dry atmosphere. If the seed cannot be extracted immediately, the freshly gathered fruits should be spread in a thin layer in a dry place in the open and stirred occasionally for several days following collection. Freshly picked pine cones and juniper berries heat rapidly if left in sacks or deep piles. Therefore, layers of fruit should not be more than 2 to 4 inches thick. After drying, the fruits can be stored temporarily in bags while awaiting extraction.

Where cone storage sheds are available, the cones can be stored in trays for drying prior to extraction of the seed (fig. 9).

SEED EXTRACTION AND CLEANING

A modern seed extractory is desirable if the size of the nursery and its production schedule require large quantities of pine or spruce seeds. Less elaborate facilities suffice when smaller quantities of cones are to be handled. At Norman, Okla., up to 60 bushels of loblolly and shortleaf pine cones can be handled per day in a 25- by 25-foot cone-drying room. This drying unit is heated by gas (a 112,000 B.t.u. heater). Cone trays with a screen-wire bottom are made from 2 by 4's.

F-488915

FIGURE 9.—A cone storage shed at Big Sioux Conifer Nursery, Watertown, S. Dak. The cone storage portion of the building on the right is connected directly to the extractory.

F-502087

FIGURE 10.—Ponderosa pine cones placed on racks for extraction. Tarpaulins are used to prevent the loss of seed as the cones open. Bessey Nursery, Halsey, Nebr.

Although artificial heating results in greater extraction of the seed, solar heat and air drying often are satisfactory. The cones are placed out of doors in the sun on screens or tarpaulins (fig. 10). When open, they are shoveled into a screened tumbler; the seeds fall to the floor from one end of the tumbler, and the empty cones discharge from the other end. Further recovery of seed remaining in the cones can be secured by threshing them in an improvised combine or low revolution-per-minute hammermill. The efficiency of the solar extraction can be raised materially by allowing the cones to remain on the trees almost to the time of natural seed fall.

Fresh cones that have been predried in the sun will open readily; cones that have been stored may not. Maki (1940) found that cones fail to open satisfactorily when they have been dried out gradually in cool, dark places or have been stored in sacks and other containers where the scales could not open. Cones that have been stored long enough to become dry without opening may have to be moistened before they will open satisfactorily.

Dewinging of ponderosa pine seed is simplified by wetting. The seed is sacked and dipped in water long enough to swell the wing collars, or loose seed is spread in layers one-half to 1 inch deep and moistened. The seed is then placed on screens to dry with occasional stirring. When sufficiently dried, the wings are loose and can be fanned out.

Small quantities of dry seed can be dewinged by rubbing them in a cloth sack and then winnowing. For large quantities, some type of mechanical dewinger is needed. Lanquist (1954b) cleaned and dewinged seed in a machine adapted from a dustless hammermill that was designed by the Soil Conservation Service (Steavenson 1940). The hammers of the mill are replaced by a brush arrangement for dewinging the seed. The screen size depends on the seed size. With a brush speed of 184 r.p.m., almost all of the wings are removed in one operation. The mechanical dewingers must be used carefully to avoid injury to the seed (U.S. Forest Serv. 1948).

Seed extraction for the juniper species is mostly a process of running the berries through a fanning mill to remove foliage and other trash, macerating the berries, and removing the pulp residue by flotation and screening. Numerous types of macerators have been successfully employed.

A macerator developed by the Forest Service is often used (fig. 11). It is of all-metal construction and is built on the principle of a threshing machine with cylinder and concaves. The capacity of the macerator is governed by the length of the cylinder, which varies from 12 to 18 inches. The machine may have fixed plates, but adjustable macerating plates are available so that different clearance widths can be obtained for the various types of seeds processed. A good power unit for operating this machine is a 1-hp. electric motor or a small gasoline engine. Commercial models which operate similarly are also available.

The machine is run at a rather high speed, with the discharge slide wide open to thresh the fruit from the leaves and twigs. The seed is separated from the pulp by closing the discharge opening and decreasing the speed. This machine, equipped with a 12-inch cylinder with teeth spaced to provide three-eighth-inch clearances, has handled 1,000 to 1,500 pounds of juniper berries per day (Engstrom and Stoeckeler 1941).

At the Bessey Nursery, a large meat grinder is now used. The grinder is electrically driven and operates in a normal manner, except that the cutting blade is reversed on the shaft to prevent injury to the seed as

F-502088

FIGURE 11.—Macerating juniper berries in a specially constructed macerator. The machine can also be used to thresh the fruit, leaves, and twigs by operating it at a rather high speed, with the discharge slide wide open.

the berries are forced through the disk sieve. The berries can be run through the grinder as fast as one man can fill the grinder and handle the pulp. For complete maceration, they are run through the grinder two or three times without water.

A hammermill was used extensively by the Soil Conservation Service nurseries to extract juniper seed. The mill was run at a speed of about 400 r.p.m. by a farm tractor with a flat-belt drive. The fruit was poured into the mill, and ample quantities of water were supplied by one or two garden hoses (Steavenson 1940). After 14 to 20 minutes of treatment, the clean seed had collected on a screen in the bottom of the mill. This material was then dumped on screens to dry. Finally, it was run through the fanning mill to separate the seeds from the debris.

After most maceration processes, the seed usually needs further cleaning. First the mixture of seed and pulp is soaked for 1 or 2 days in a lye solution (1 teaspoon of lye to 1 gallon of water). This separates the seed from the remaining pulp, which is very oily and resinous, and which would hinder seed washing and flotation and subsequent seed stratification. After the lye treatment, the mass is dumped into screened trays and thoroughly washed by forcing water through it under pressure to remove the lye and most of the remaining pulp; only the berry hulls and seed are left.

The sound seed can usually be separated from the berry hulls and from floaters (empty or light seed) by flotation (Engstrom and Stoeckeler 1941). This method is based on variation in buoyancy under agitation in water. Some of the macerated material is placed in a slightly tilted large washtub into which a stream of water from a garden hose is directed at such an angle as to create a rotary swirl and a lifting effect on the material. Slight stirring of the material in the bottom of the tub is also necessary. The pulp and light seed will float to the surface and spill over the edge of the tub as the water overflows. The seed is then dried on tarpaulins in the sun or on trays in the extracting room. Finally it is fanned to remove the remaining empties and small seeds.

After extraction, the moisture content of seeds should be determined, particularly that of conifer seeds scheduled for several years' storage. The preferred moisture content of seeds used in Prairie-Plains nurseries is detailed in the following section on seed storage.

Kiln-dried or air-dried seed from dry climates often need no additional drying. Wahlenberg (1925) recommended that, when possible, ponderosa pine seed should be dried at ordinary temperatures instead of in a kiln. A seed drier may be used to dry seed following extraction, especially during winter when air drying outdoors is not feasible and inside drying space is limited. A rotary drier, consisting of a screen-wire cylinder 32 inches long and 32 inches in diameter with wooden ends of one-half inch lumber, has been used by the Forest Service (Engstrom and Stoeckeler 1941). The three 1- by 3-inch baffleboards, equally spaced within the periphery of the cylinder, pick up the seed as the drum revolves and slowly spill it in a thin stream as each baffle reaches the highest point. Warm air from the heater, forced through a revolving cylinder by an electric fan, hastens the evaporation of moisture from the seed. The optimum speed for the cylinder is 12 to 15 r.p.m. There is danger, however, of too rapid or excessive drying.

SEED STORAGE

Because of the irregularity of conifer seed crops, it is essential that stocks of seed be kept for several years. Lack of knowledge on proper storage conditions resulted in heavy losses during early reforestation efforts. Therefore, extensive research has been done on seed storage.

One of the two critical factors is moisture content of the seed. Satisfactory ranges or levels of moisture content prior to storage have been determined to be as follows: Pine species other than southern pine, 5 to 8 percent; spruce including white and Engelmann, 8 percent (Holmes and Buszewicz 1958); loblolly and shortleaf pine, 9 to 12 percent (Wakeley 1954); and eastern redcedar, 7 percent (U.S. Forest Serv. 1948).

To maintain these moisture contents it is usually more practical to use sealed containers than to have the whole storage chamber kept at a low humidity. A common type of seed container is a cylindrical can about 36 inches tall and 18 inches in diameter fitted with a bronze screwcap and sealed with a rubber gasket. Such cans have an approximate capacity of 150 to 160 pounds of conifer seed. Cardboard containers of various sizes are used at the Towner Nursery. The seed is put in a polyethylene bag and placed in the container. A press-on lid is held in place by wire clamps. At the Oklahoma State Nursery at Norman, 5-gallon glass bottles with screwcaps are used. Each bottle holds 25 pounds of seed. Small lots of seed can be kept in jars or similar containers sealed with paraffin.

Low temperature is the other essential condition for successful storage. Dry cold storage at 32° to 40° F. in sealed containers is satisfactory for prolonged storage of seeds of all pines, spruces, junipers, Arizona cypress, oriental arborvitae, and larches (U.S. Forest Serv. 1948). Seed apparently can withstand subfreezing temperatures for several years without injury if it is stored in sealed containers and has a moisture content of less than 7 percent. Hence, most commercial cold-storage facilities can be used to store seed (Rudolf 1952). Seed of ponderosa, loblolly, and shortleaf pines and of white spruce kept well for 4 to 7 years at subfreezing temperatures (Barton 1935).

In some of the larger Plains conifer nurseries, seed is stored in specially constructed seed-storage facilities. At the Towner Nursery, a 10- by 10-foot walk-in cooler is used. Other nurseries store seed in refrigerated planting-stock storage warehouses. At the Bessey Nursery, several large refrigeration units are used.

A few examples will illustrate the effectiveness of dry cold storage and the magnitude of seed loss that may occur where improper methods are used.

Ponderosa pine seed sealed in airtight containers and held at 41° F. for 10 years maintained their viability. One seed lot stored for 17 years and the other for 18 years had a viability of 75 to 94 percent (Schubert 1954). Under similar storage conditions, Arizona cypress seed retained viability for 11 to 20 years.

Oriental arborvitae seed has retained viability (95 percent) for 18 years when stored in sealed containers and placed in refrigerators.[5]

Ponderosa pine seed with a moisture content of 15 percent when stored maintained their germination after 3 years' storage in canvas bags at −4° C. (Barton 1954). Germination was reduced 20 percent during the same period when seed with a moisture content of 17 percent was stored at −11°.

Germination of Austrian pine seed with a moisture content of about 8.5 percent, stored for 4 years in sealed containers at 2° C., was 63 percent, compared with an initial germination of 72 percent. Seed from the same lot stored in a sack in an unheated room showed only 1-percent germination.

The seed of white spruce with a moisture content of 6.7 percent showed an insignificant loss in germination after 7 years' storage in sealed containers at 0° and −18° C. When stored in sealed containers at room temperatures, none of the seed germinated (Allen 1957).

Juniperus seed can survive even longer periods of storage when stored dry in sealed containers at low temperatures. The seed of Rocky Mountain juniper stored in a cool cellar (50° to 65° F.) showed about 30 percent germination after 3½ years (U.S. Forest Serv. 1948). Johnsen (1959) found that seed of three western species could survive long periods of dry storage in bags or jars. The germination of 45-year-old Utah juniper seed was 17 percent; 21-year-old one-seed juniper, 54 percent; and 9-year-old alligator juniper, 16 percent.

SEED TESTING

Accurate tests of the number of seeds per pound, purity, and germination percent are necessary if seed is to be sown in the nursery at rates that will assure approximately the desired stand per square foot. Thin stands waste space, allow weed growth, and increase planting stock costs. Overdense seedbeds produce undersized, spindly stock with a high cull percent and poor survival or growth. The procedures used in seed testing are thoroughly discussed in the "Woody-Plant Seed Manual" (U.S. Forest Serv. 1948). New tree seed testing recommendations of the Association of Official Seed Analysts are expected to be available in 1965.

Care must be taken to obtain a representative sample

[5] Communication with Michel Afanasiev, Forestry Dept., Oklahoma A. & M. College, Stillwater, Okla., April 1958.

of seed. With a conventional grain probe, a uniform, equal sample may be taken from the top to the bottom of the container. Where seed lots of the same year and origin are stored in more than one container, samples from each container are taken and mixed. This sample must then be subdivided until a small representative sample of 2,000 to 3,000 seeds is obtained. A sample can be subdivided by mixing, quartering, and again mixing, or by using a mechanical device.

Perhaps the most reliable tests of seed viability are those in which the seed is allowed to germinate naturally under ideal conditions of moisture and temperature. Usually 30 to 60 days are required, so tests are run before the spring sowing season.

In many Plains nurseries, 200 to 250 seeds of any one lot are sown in flats that are filled with washed and sterilized fine sand (fig. 12). The exact number of seeds is counted and broadcast uniformly over the sand or lined out in rows. The seed is pressed lightly into the surface, sand is sifted over it, and the surplus is struck off with a slat to obtain uniform depth. The flat is then labeled with the seed collection or accession number.

For species that germinate promptly without pretreatment, the flats are placed in a greenhouse or in a germination room that can be lighted during the normal daylight hours and heated to provide a diurnal fluctuation from 68° to 86° F. (Stoeckeler and Jones 1957). The flats are watered daily. Once germination starts, the seedlings are removed every 1 to 3 days and recorded. Ungerminated seeds remain in the flats until germination appears complete, usually in 30 to 60 days.

Germination can also be tested by placing the seeds between moist blotter paper in petri dishes. The blotters should be supported above the free water on the bottom of the petri dish, but should be connected to it

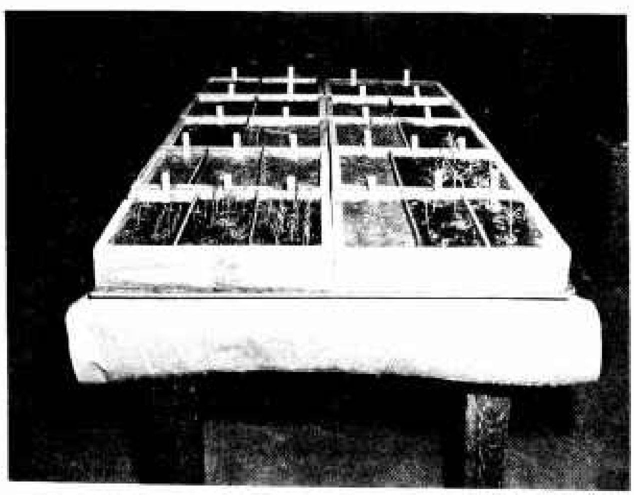

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FIGURE 12.—Ten- by fourteen-inch flats used at the Bessey Nursery, Halsey, Nebr., in germination tests of coniferous seed. A mixture of half sand and half peat is being used as a medium.

by strips of blotting paper. The seed should be kept moist but not wet. Equipment should be sterilized with heat or boiling water to reduce mold.

A Jacobson germinator [6] or similar device can be used in lieu of petri dish tests (U.S. Forest Serv. 1948). A number of constant-temperature germinators are available. These devices greatly speed the process of determining potential germination.

Cutting tests are commonly used by nurserymen for a rough determination of seed quality. They are useful as emergency guides in fall sowing of freshly collected seed that have embryo dormancy, or for other seed that have not been tested. In cutting tests, several hundred seeds are cut open with a sharp knife, and the percentage of good seeds is determined. Good seeds are well filled and have white or cream-colored kernels.

Another rapid method of obtaining the germination value for dormant seed is the excised-embryo test. The embryos are dissected from the seeds, placed on moist, sterile cotton in petri dishes, and kept at about 70° F. for 2 to 31 days. During this period live embryos show various types and degrees of development, such as enlargement of the cotyledons, development of green color, and even emergence of radicle (Flemion 1941). Those that are not viable discolor and soon deteriorate. The excised-embryo test has worked successfully on *Juniperus* species, ponderosa pine, and Douglas-fir (Heit 1955). This test eliminates the effect of seedcoats and checks the condition of the embryo, where the life of the plant exists.

The most rapid viability indicator is a biochemical method that uses tetrazolium salts. The embryos are exposed and placed in a testing solution consisting of 0.5 gram of 2,3,5-triphenyl tetrazolium chloride in 200 cubic centimeters of water. The chemical stains living tissues a carmine red within 24 hours. Seed viability results obtained with a test using tetrazolium chloride compared closely with those from the excised-embryo test (On 1952). Both gave significantly higher germination capacities for ponderosa pine and Douglas-fir than those obtained by sand flats. The tetrazolium (TZ) test has many inherent advantages over other testing methods, but the accuracy of results depends on the qualifications of the analysts who interpret it (Colbry et al. 1961). It cannot be recommended for general usage.

Facilities for testing tree seed are not available at any of the Plains States seed-testing laboratories. However, tree seeds used in Plains nurseries can be tested for a fee at the Eastern Tree Seed Testing Laboratory, Macon, Ga., cooperatively maintained by the Georgia Forestry Commission and the U.S. Forest Service; the Oregon Seed Testing Laboratory at Corvallis; or the Department of Seed Investigations, New York State Agricultural Experiment Station, Geneva.

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[6] Mention of commercial products or specific firms does not constitute an endorsement by the Forest Service or the U.S. Department of Agriculture.

The fees are prorated according to the total number of tests made during the season. They have averaged $10 to $12 per test. Tests are run for Federal, State, and private nurseries, and for commercial seed dealers.

SEED DORMANCY AND PRETREATMENT

Seed of some conifers, including ponderosa, Austrian, Scotch, and jack pine, germinate satisfactorily without pretreatment. Other seed, including that of some spruces, show embryo dormancy and germinate better if fall sown or stratified prior to spring sowing. Germination of some seed, such as eastern redcedar and Rocky Mountain juniper, may be delayed by the presence of an impermeable seedcoat in addition to embryo dormancy.

Usually dormancy can be overcome by a period of cold, moist stratification, during which certain chemical changes occur in the seed, preparing it for prompt germination. Pretreatment of seed frequently results in more rapid, even, complete germination. Seed is used more efficiently, and losses from disease are reduced. It is decidedly beneficial when seed that has been stored for some time is to be sown. However, stratification should not be regarded as an alternate means of seed storage since seed has been ruined by overlong stratification.

The seed of most pines used in Plains planting will germinate well without stratification. Ponderosa pine lots usually do not need stratification, but it will hasten and improve the germination of some lots. Mirov (1936) cites the need of pregerminative chilling in the presence of moisture; he obtained a 7-percent increase in germination from seeds stratified for 3 months at 40° F. Taylor (1941) obtained more rapid and complete germination and a more even stand of seedlings from ponderosa pine seed stratified for 30 days at 34° to 40°. He cited certain disadvantages of using stratified seed, including poorer handling by mechanical sowers, less accurate control of sowing rates, and injury to the seed by acid treatment of the beds after sowing. The germination of loblolly and shortleaf pine is much improved by cold, moist stratification for 30 days at 30° to 41° (Wakeley 1954).

White spruce, including that of Black Hills origin, shows strong dormancy, while that for blue spruce was moderate to nonexistent. Good germination of these species was obtained after 50-day stratification at temperatures from 34° to 49° F. (Cram 1951).

Germination of Arizona cypress seed is usually very low, probably because of the poor quality of seed produced commercially and possibly also because of seed dormancy. Cold stratification in peat moss for 20 days is recommended.[7]

The erratic germination of juniper seeds commonly used in Plains planting has long been a problem in private nurseries. Seeds of eastern redcedar have dormant embryos which require 100 to 120 days of stratification at 35° to 40° F. to afterripen (Pack 1921, Taylor 1941). In a series of tests to determine the most favorable temperatures for afterripening, Barton (1951) found that 41° gave the best results, that 33° was less effective, and that 50° was totally ineffective. Germination was arrested in afterripened seed for as long as 3 months by storing ungerminated seed at 15° to 20° (Afanasiev 1955). Germinating seed was injured by the subfreezing temperatures, and it did not resume growth after storage. A reduction in germination occurs if seed is allowed to dry after stratification and before sowing (Afanasiev and Cress 1942a).

Dormancy of the seed of Rocky Mountain juniper is essentially the same as that of eastern redcedar except that chemical changes during afterripening are slower and normally require 14 to 16 months after seed maturity for free germination without pretreatment (Afanasiev and Cress 1942b). Beds of this species have lain over without germination for 1½ years from the time of fall seeding despite depulping and 3 months of stratification at controlled temperature. Hence, it seems best to keep this species in stratification for 6 months before seeding in the spring. Then it usually germinates 2 to 3 weeks after seeding.

The presence of impermeable seedcoats in a large percentage of juniper seed will prevent complete germination. Seedcoats may be made permeable by exposure to moisture at a temperature of approximately 25° C. (77° F.) for 2 to 3 weeks. Soaking for 30 minutes in concentrated sulfuric acid is also effective; this treatment is given before the seeds are placed at low temperatures for breaking the dormancy of the embryos (Barton 1951).

Scarification has been used to increase the permeability of juniper seedcoats. Mechanical scarification of the seed in a steel drum lined with sandpaper was used successfully at the Bessey Nursery as early as 1934 (Dayharsh 1934). A more efficient type of scarifier, consisting of six vertical sandpaper-covered disks, was useful for small experimental lots of seed (Stoeckeler and Baskin 1937). For larger lots of seed, where comparatively light scarification is needed, a modified Ames scarifier can be used (Chapman 1936).

The methods used to induce germination of juniper seed and the results obtained have varied depending on location. In some places one method will produce even, prompt germination, whereas the same procedure used elsewhere will not. The two species, eastern redcedar and Rocky Mountain juniper, may also react differently. The two methods commonly used are planting the seed in the fall shortly after collection and planting in the spring following stratification.

Consistently prompt germination of eastern redcedar in Oklahoma has been obtained in fall sowing (Engstrom 1950, 1955). The clean, depulped, unstratified seeds are sown about December 10, covered with one-eighth to one-fourth inch of sawdust, watered, and then covered with 0.002-gage (thickness) polyethylene film. The film is in 1,000-yard rolls and is 53 inches wide. Burlap is laid over the plastic film, and both are pinned

[7] U.S. Forest Serv. Fourth Ann. Rpt., Fiscal Year 1957, Region 8, Eastern Tree Seed Testing Laboratory.

to the soil at intervals of about 4 to 6 feet with 5-inch soil staples made of No. 9 wire.

Germination starts about March 1 and is completed by March 10 to 15. As soon as germination starts, the burlap and plastic film are removed from the beds, snow fence is rolled out on the 1- by 6-inch bedboards to provide half-shade, and the burlap is laid on top of the half-shade for 10 days. The burlap conserves moisture and guards against early spring freezes. In one instance, air temperatures dropped to 12° F. without harm to the seedlings. With this method, redcedar seed completes germination about 3 weeks earlier in the spring than does seed covered only with burlap. Favorable results are also obtained when it is used with Austrian and ponderosa pine.

Fall sowing of eastern redcedar is also being tried experimentally at the Bessey Nursery. The cedar berries are collected as soon as they are ripe and are depulped. The seeds are dried just enough to permit drill seeding, sown, covered with burlap, and mulched with straw or hay. Germination has been sufficient to produce good stands the following spring.

At the Mandan nursery of the Soil Conservation Service, October sowing of *Juniperus* produced uniform germination from 1946 through 1949. Seed of Rocky Mountain juniper was stratified at 45° to 50° F. for a 4-month period prior to sowing, while that of eastern redcedar was sown dry. After seeding, the beds were mulched with a 4-inch layer of straw and shingletow and watered until freezeup. The mulch helped to prevent (a) winter drying when snow cover was absent, (b) alternate freezing and thawing, and (c) premature germination in the spring.[8]

SELECTION OF THE NURSERY SITE

Successful planting of conifers in the Plains begins with the selection and development of the nursery site. This decision is a prime factor in determining the quality and cost of the planting stock. In fact, the success or failure of the nursery may depend on the site selected. Once the nursery is established, a change in location is difficult and expensive.

The Plains have an essentially adverse environment for growing coniferous seedlings. Common problems are excessive alkalinity of soil or water, water shortages, poor internal drainage and crusting and baking of some soils, lack of mycorrhizal fungi, wind erosion, frequent winter injury, frost heaving, hail, heat injury, much damping-off, and damage by rodents and birds. These are a formidable array of difficulties for those planning to grow conifers in the Plains. All sites have some problems. Therefore, one with the fewest adverse factors must be chosen.

The major considerations in the selection of a nursery site are the soil and the water supply. Other important items requiring attention are the availability of markets, utilities, and labor; the shape, topography, and size of tract; and the crop history of the land.

SOIL

A suitable soil in the nursery is a prime requisite since the characteristics of the soil influence almost every nursery operation, from sowing the seed to shipping the stock. Soil texture, soil fertility, its reaction, and its alkalinity are discussed in this section. All aspects of the management of the nursery soil are discussed in detail in a later section.

Soils with textures that would be considered somewhat droughty for dryland farming are the ones best adapted to conifer seedling and transplant culture. The irrigation equipment, an essential feature of any Plains nursery, will overcome a trend to droughtiness, which is an inherent feature of all soil profiles with properties desired for a conifer nursery.

The surface and subsurface layers of soil to a depth of at least 10 feet should be sands, loamy sands, or light sandy loams. Good internal drainage is necessary, since alkalinity problems, especially upward movement of alkalies from evaporation, are at a minimum in such soils. Areas with tight soils or with clay bands in the substrates must be avoided. So too must extremely coarse, gravelly substrates, which permit a high loss of irrigation water.

In terms of mechanical analysis, the top 12 to 24 inches of soil should have a silt-plus-clay content between 12 and 35 percent, with subsoils preferably in the 5 to 20 percent range. Tests can readily be made with a field test kit (Wilde and Voigt 1955) or performed for a fee at the soil testing laboratory of the State agricultural college.

Commercial nurserymen growing balled and burlapped stock prefer somewhat finer textured soils for their lining-out beds, used for the second and successive transplantings. Soils may be loams or even silt loams, with a silt-plus-clay content of as much as 60 percent. Such lining-out tracts receive less watering than seedling or "first transplant" beds; hence, the salinity problem is not as critical.

Sandy soils have advantages over the heavy soils for seedling and transplant culture. They have better water intake and better soil-air-moisture relationships; they crust less, can be worked sooner after rain or irrigation, have fewer alkali problems, and produce more fibrous root systems (Anderson and Cheyney 1934, Howell 1932). The trees can be lifted, dug, and transplanted with less power and less damage to the rootlets. The disadvantages of sandy soils are their need for more frequent watering, their lower fertility, and their greater subjection to wind erosion.

The initial nutrient level of the proposed conifer nursery site before fertilization, particularly for areas devoted only to seedlings and transplants, can be somewhat lower than is desirable for farm crops. More important is the need for a friable, deep, rather porous, slightly acid soil free from harmful alkalies. Such soils

[8] Personal communication with A. E. Ferber, Soil Conservation Service, Denver, Colo., August 1960.

are likely to be deficient in available phosphorus. They may also contain less total nitrogen and organic matter than is necessary for conifer production. But these deficiencies can be remedied by means described in the section on "Soil Management."

The pH of the prospective nursery site is quite likely to be 6.0 to 7.2 for soils that have not been irrigated. Use of soils with a pH of 7.5 or higher, especially those of fine texture, is almost certain to result in insoluble or very costly problems of pH adjustment, due to an excess of carbonates and alkalies. (See Engstrom and Stoeckeler 1941 and Richards et al. 1954 for more discussion of this problem.) However, for nursery blocks that produce balled and burlapped stock from transplanted seedlings, satisfactory growth has been obtained in soils with a surface pH as high as 7.8, such as in the High Plains of northern Texas near Lubbock, where oriental arborvitae, various junipers, and some of the drought-hardy pines are being produced.

Use of soils with more than 500 p.p.m. (parts per million) of total soluble salts has created difficulties in the growing of pines and spruces, owing to chlorosis, excessive damping-off, crusting of salts on the surface due to evaporation of irrigation water, and phosphate and other nutritional unbalance.

WATER SUPPLY

Most States have laws on water use, particularly on the pumping of water from lakes, streams, and reservoirs. Some States require registration of pumps drawing irrigation water from wells. The State Geologist can provide information.

Experience has shown that irrigation water for use in Prairie-Plains conifer nurseries should have less than 200 p.p.m. of total dissolved solids (Engstrom and Stoeckeler 1941). For sensitive crops, as defined by the Salinity Laboratory at Riverside, Calif., the sodium adsorption ratio of the irrigation water should be under 10 and the boron content less than 0.5 p.p.m. (Richards et al. 1954). Most conifers grown in the Prairie-Plains are in the sensitive-crop category, so these criteria should be considered approximate permissible maximums. In nurseries devoted to the growth of balled and burlapped stock, where the water need is less than for seedbeds or transplants, water with as much as 400 to 500 p.p.m. of dissolved solids has been used. Higher amounts may be permissible with proper periodic soil treatments, such as acidification.

Even though irrigation water meets the above specifications, alkalinity problems can still occur. Continued irrigation for several years may result in an unsatisfactory condition in the soil surface. An example is the water supply at the Towner Nursery, Towner, N. Dak. Analysis at the time of nursery establishment showed 187 p.p.m. of total dissolved solids in the irrigation water. Two years of heavy watering raised the average reaction (pH) of the soil surface from 6.5 to 7.5, and seedlings of sensitive species began to show the effects. Stunting, patchiness, poor stands, and a low percentage of plantable trees were observed in some beds. The condition was readily corrected with acidifying materials.

Water drawn from wells may be somewhat less alkaline than surface water taken from streams, and it is also free of weed seed. Moreover, salinity of water in some streams tends to increase as the river stage drops; at this time water needs in the nursery may be quite high.

The irrigation water required depends on the size of the nursery, its latitude, relative acreage of seedbeds and transplants, amount and distribution of rainfall during the growing season, method of irrigation, stand density, protection by windbreaks, and amount of shade on seedbeds. Nurseries in the Southern Plains often need more water than those in the Northern Plains. Nurseries in the Western Plains require more irrigation water than those farther east, where the rainfall is higher. Flood or furrow irrigation requires more water than sprinkler irrigation. More water will be needed in abnormally hot seasons such as occurred in 1936.

During years of normal precipitation the total irrigation water needed for nurseries growing both seedlings and transplants is estimated to be as follows:

Location	*Annual supplemental water needs (inches)*
Northern Plains	10–15
Central Plains	15–25
Southern Plains	25–30

In years of abnormal heat or drought, 5 to 8 inches must be added to the above amounts. Most nurserymen will prefer to have a water system with a capacity sufficient to water the necessary area in daylight hours, and a surplus capacity for watering on a round-the-clock basis in seasons of drought or extreme heat. A flow of 450 gallons per minute is equivalent to 1 acre-inch of water per hour.

For nursery blocks devoted to balled and burlapped stock spaced in rows 40 to 80 inches apart, a capacity of 10 to 20 gallons per minute per acre is ample.

For sprinkler irrigation, per-minute capacities of 50 and 30 gallons of water per acre of seedbeds and transplants, respectively, are sufficient. Extensive use of flood irrigation will require 30 percent more water.

AVAILABILITY OF MARKETS, UTILITIES, AND LABOR

The nursery site should be close to, or slightly south and east of, the market center of the area to which stock is to be shipped. The warmer climate to the south permits lifting of the stock when the planting season opens. If other factors are equal, the more easterly locations have the advantage of greater rainfall.

The nursery location should have good access to railroad, highway, telephone, and telegraph facilities. The type of planting stock distribution anticipated naturally has a bearing on transportation needs. However, since deficiencies cannot be remedied easily, adequate service at the start is virtually essential. The nursery must be on an all-weather road. Electric power is almost a necessity for light, seed and planting stock refrigerators, and other miscellaneous needs.

There must be an adequate supply of labor near the nursery site. The amount of labor needed varies widely, depending on the size of the nursery, the extent of mechanization, the degree of chemical weed control, and the amount and kind of stock grown. For about 6 weeks in the early spring, when labor needs are at a peak, about 2.0 laborers are required per acre of nursery seedbed and 1.5 laborers per acre of transplants. For 2½ months in late spring and early summer, the average requirements may be about 1.5 laborers per acre. And for about 3 months in late summer and fall, the requirements are 0.75 laborer per acre. The average required for this 7-month period is about 1.3 laborers per acre. Women and girls may constitute as much as 30 to 50 percent of the labor force and often do most of the transplanting, grading, and counting of stock.

SHAPE, TOPOGRAPHY, AND SIZE OF TRACT

Ideally the nursery tract should be square or rectangular; the long dimension should not be more than twice the short one. However, the best site available may be a long, narrow tract. An efficient layout is more difficult to obtain on such a piece of land, but the disadvantages can be minimized by careful planning.

A level tract with stone-free, deep loamy sand or light sandy loam soil is desirable. Such sites are most often on a stream terrace or glacial lake bottom. If furrow irrigation is anticipated, the land should have a gentle slope in one direction, preferably 0.1 to 0.2 percent on fine sandy loams, and slightly more for loamy fine sands. On very sandy soils, which absorb water rapidly, slopes up to 0.5 or 1.0 percent have been successfully irrigated in furrows. On land with more slope, it may be necessary to lay out the beds on contours with terraces.

Existing wind protection can often be used in choosing a nursery site. Natural or planted trees or situations favored by local topography may reduce the need for, or time required to obtain, adequate protection.

The tract must be large enough to meet immediate and preferably long-range production goals. Space calculations also must consider the need for cover and soil improvement crops in the rotation.

To compute nursery acreage needs per million trees for any specific age class, the probable production of usable trees per square foot of seed and transplant beds must be known. An average of 40 usable seedlings or 5 usable transplants per square foot of bed is a reasonable assumption for Prairie-Plains conditions. On this basis the net space requirements per million trees produced will approximate those in table 4. Other seedling and transplant densities may be used similarly in determining net space requirements of individual nurseries. For example, where seedlings are field planted directly, an average need of 30 trees per square foot might be assumed.

TABLE 4.—*Net space requirements per million trees of seedlings and transplants, excluding paths and roads*[1]

Age class of stock	Acres required for—					Total
	1st year	2d year	3d year	4th year	5th year	
1–0	0.57	......	......	......	......	0.57
2–0	.57	0.57	......	......	......	1.14
3–0	.57	.57	0.57	......	......	1.71
1–1	.57	4.59	......	......	......	5.16
2–1	.57	.57	4.59	......	......	5.73
1–2	.57	4.59	4.59	......	......	9.75
2–2	.57	.57	4.59	4.59	......	10.32
3–2	.57	.57	.57	4.59	4.59	10.89
2–3	.57	.57	4.59	4.59	4.59	14.91

[1] Figures are based on 40 plantable seedlings and 5 plantable transplants per square foot.

The gross producing area of the nursery should be three to four times the net space requirements. An area of this size allows for paths, roads, and other nonproduction areas, and for cover crops in the rotation. Additional space must be allowed for windbreaks.

The minimum size for nurseries producing several million seedlings and several million transplants is 20 to 40 acres in actual tree production, with 10 to 20 additional acres in reserve or cover crop.

CROP HISTORY OF LAND

The class of land most likely to be selected for a conifer nursery site is former farmland. Such land is usually free or nearly free of the more serious noxious weeds such as quackgrass and field bindweed. Areas that have been in intertilled crops are more amenable to immediate sowing of seedbeds than are those formerly in small grain or hay crops. The weed problem in the latter areas is likely to be serious for several years.

There may be tracts of grassland, pasture, or wild hayland suitable for nursery development. These generally would not be suitable for tree production for about 2 years after breaker plowing. They should preferably be summer fallowed for 1 year and planted to an intertilled agricultural crop the second season. Only then is the soil likely to be in good enough condition for nursery production.

More rarely, abandoned agricultural land with suitable topography and reasonably adequate fertility, but with a somewhat droughty nature, may be used. It may have been abandoned because of its droughtiness. However, if other factors are favorable, if the area has good internal drainage, adequate topsoil depth, proper soil texture, and an adequate supply of water of the desired chemical properties, it may be considered a potential nursery site. But the weed problem would probably be so serious as to require 2 years of development by the method described for grassland.

DEVELOPMENT OF THE NURSERY SITE

After the nursery site has been selected, it must be developed. Physical data on soil and ground relief characteristics must be obtained during or immediately after acquisition for use in planning the development. Careful groundwork will lessen the need for costly future alterations.

An accurate map with a scale of 1 inch to 50 to 100 feet should be made. On this map the layout of the water system, roads, windbreaks, and buildings can be diagrammed. A topographic map with a contour interval of 0.5 to 1.0 foot is useful in leveling and other necessary ground fitting. If flood irrigation is planned, such a map can be used to determine the location of the main ditches or flumes and grassed waterways. It also can provide the basis for subdividing the nursery.

SUBDIVIDING THE NURSERY

The site selected for a nursery is usually smooth, but there are always some small humps and minor depressions that need to be leveled. Where the cut or fill is more than 3 or 4 inches, it is desirable to stockpile the topsoil, perform the leveling, and replace a normal cap of topsoil on the disturbed area (Mony 1935).

Trash, straw piles, scrap lumber from old buildings, and other debris should not be burned on any area to be devoted to the growing of trees. Experience has shown that trees grown on the burned areas are more subject to damping-off, and growth is depressed, at least on the first crop.

On land with more than a 1-percent slope, the nursery should be subdivided on the contour. The degree of slope and the type of irrigation to be used determine the specific pattern. A system of broad-base terraces should be developed at intervals of 100 to 150 feet. The vertical interval may be 1 to 3 feet. At Norman, Okla., hedge windbreaks were established on the downhill side of each terrace. At most nurseries, slat-wire snow fences are preferred, since they occupy less space, can be readily moved, and harbor no disease or insect pests as living hedges sometimes do.

Terraces in areas where rather high-intensity rains occur should have some grade. Those at the State Nursery at Norman, Okla., have a grade of about 1 percent, with a vertical interval of 2 feet between terraces. The spacing of terraces, both horizontally and vertically, and their rate of fall depend on the infiltration rate of the soil, steepness of slope, crop, length of terrace, and facilities for disposal of runoff water.

Agricultural engineers have worked out detailed guidelines on the development of terraces, and numerous publications with data of local or regional application are available. The technicians of the Soil Conservation Service have helped many nursery personnel lay out a system of terraces and grassed waterways.

On level land, the irrigation system to be used is the chief factor in subdividing the nursery. A common basic subdivision is rectangular, 400 to 500 feet long and 250 to 500 feet wide. A subdivision of this size will accommodate the standard overhead irrigation system. Where portable surface-pipe irrigation with rotary sprinklers is to be used, distances from the riser to the end of the line may be 700 to 900 feet.

DEVELOPING THE IRRIGATION SYSTEM

The type of water supply that should be developed depends on the volume required for irrigation. The choice is often dictated by the quantity and quality of the water available on the nursery site.

The nurseryman must determine the best method of pumping and distributing the water. The type of pump and motive power to be used will depend on the quantity needed, the pressure desired, and the depth of the water table.

However, most nurseries in the Plains depend upon wells as a source of water. Deep wells cost more to develop and pump than shallow wells, except possibly where artesian pressure is available.

A few nurseries pump from streams and ponds. Open water sources are usually less costly to develop than wells. Several wells and pumps are better than a single one, which may break down or fail occasionally. Where multiple installations are made, they should be far enough apart to avoid overlap of their cones of depression under sustained pumping.

Well points may be adequate for small nurseries but are not recommended where a large quantity of water is required. Because of the frequent fluctuations in the depth of the water table due to long droughts and the heavy drain upon the underground water supply, it is difficult to maintain a satisfactory water level in the ordinary shallow well or battery of well points. However, this difficulty can be overcome by increasing the depth of the well as the water table drops or by constructing a deep well equipped with a turbine pump.

Most nurseries use deep-well turbine pumps to obtain their water supply. These should be installed on a contract basis, with a guarantee of development of a specific minimum amount of water per unit of time under sustained pumping of 8 or more hours.

Centrifugal pumps are satisfactory where water is pumped out of streams or shallow water tables. The suction lift should not be more than 15 feet, and 5 to 10 feet is preferred. Shallow wells are often cased with perforated steel pipe, and coarse sand and gravel are placed next to the intake to accelerate inflow of water and to reduce the rate of clogging of the screen with finer sand particles. Details of casing a well are given in Agricultural Handbook 110 (Stoeckeler and Jones 1957) and in numerous State college publications on irrigation and well development (Duffin 1955, Fischbach et al. 1957).

There are three general types of irrigation; use is made of (1) overhead pipelines, (2) sprinklers with a portable surface pipe, and (3) furrows or flooding. The overhead system is the type most widely used nationally in coniferous nurseries. It is usually the standard against which other systems are compared.

The overhead system, which is convenient and simple to operate, consists of a series of parallel pipes spaced 52 to 53 feet apart and resting on pipe supports at 12-foot intervals (fig. 13). Nozzles are spaced at 2- or 3-foot intervals on the pipe. When this system is in operation, oscillators driven by the water pressure turn the 200- to 500-foot lengths of pipe through an arc sufficient to water a strip about 28 feet wide on each side of the pipe.

Water is distributed efficiently, and maintenance costs are relatively low. The primary disadvantages are the high initial cost and rather incomplete coverage obtained when winds are blowing. Both the underground and overhead piping must be carefully planned and installed to assure top performance.

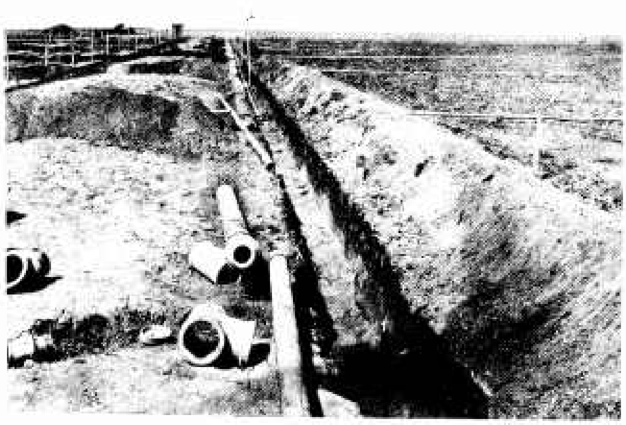

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FIGURE 13.—Installation of the 1936 expansion of the Towner Nursery water system. Note mains and risers, cross trenches across future roadway at left for risers to be installed in opposite side, and the long, parallel overhead lines shortly to be placed in the pipe supports.

F-475078

FIGURE 15.—A portable sprinkler irrigation system at the Oakes Nursery, Oakes, N. Dak. The pipe is of 4-inch diameter and is in 20-foot lengths, and the sprinklers are 40 feet apart. One well supplies 13 sprinklers; each throws 13 gallons per minute. There are three wells on the 40-acre tract. Note the excellent wind protection afforded by the dense one-row planting of Siberian elm, 25 feet high 20 years after planting.

The surface-pipe sprinkler system consists of an underground water main to which lightweight, quick-coupling metal pipes are attached (fig. 14). Each section of pipe is 20 to 40 feet long, and rotating single- or double-nozzle sprinklers are installed at 40-foot intervals (fig. 15). Lengths of 600 to 700 feet may extend from the underground water mains.

The nozzle sizes used in the rotating type of sprinkler should generally be one-eighth or three-sixteenths inch in diameter, especially for first-year seedbeds; nozzles of larger diameter throw so much water that there is much undesirable splash and soil movement in the beds. For second-year seedbeds and for transplants, larger nozzles would be permissible since soil splash is not as serious a problem, even with nozzle sizes putting out as much as one-half inch of water per hour. The usual capacity of sprinkler heads used in conifer nurseries is 9 to 18 gallons per minute.

The initial cost of the surface-pipe sprinkler system is less than that of the overhead system. This method is more flexible and therefore better adapted to the smaller nursery. But it is less convenient. Distribution of water is not as uniform. Splashing and soil movements are likely to be greater problems.

More details on sprinkler watering, estimates of water needs, and other aspects of irrigation are available in publications by Fogel (1957), Monson (1952), Monson et al. (1953), Thorfinnson et al. (1955), Wiersma (1955, 1956), and Woodward and Gilden (1955).

Flood or furrow irrigation should only be used as a supplement for the sprinkler systems in conifer nurseries. The porous soils required for best conifer production cause uneven distribution of water, excessive

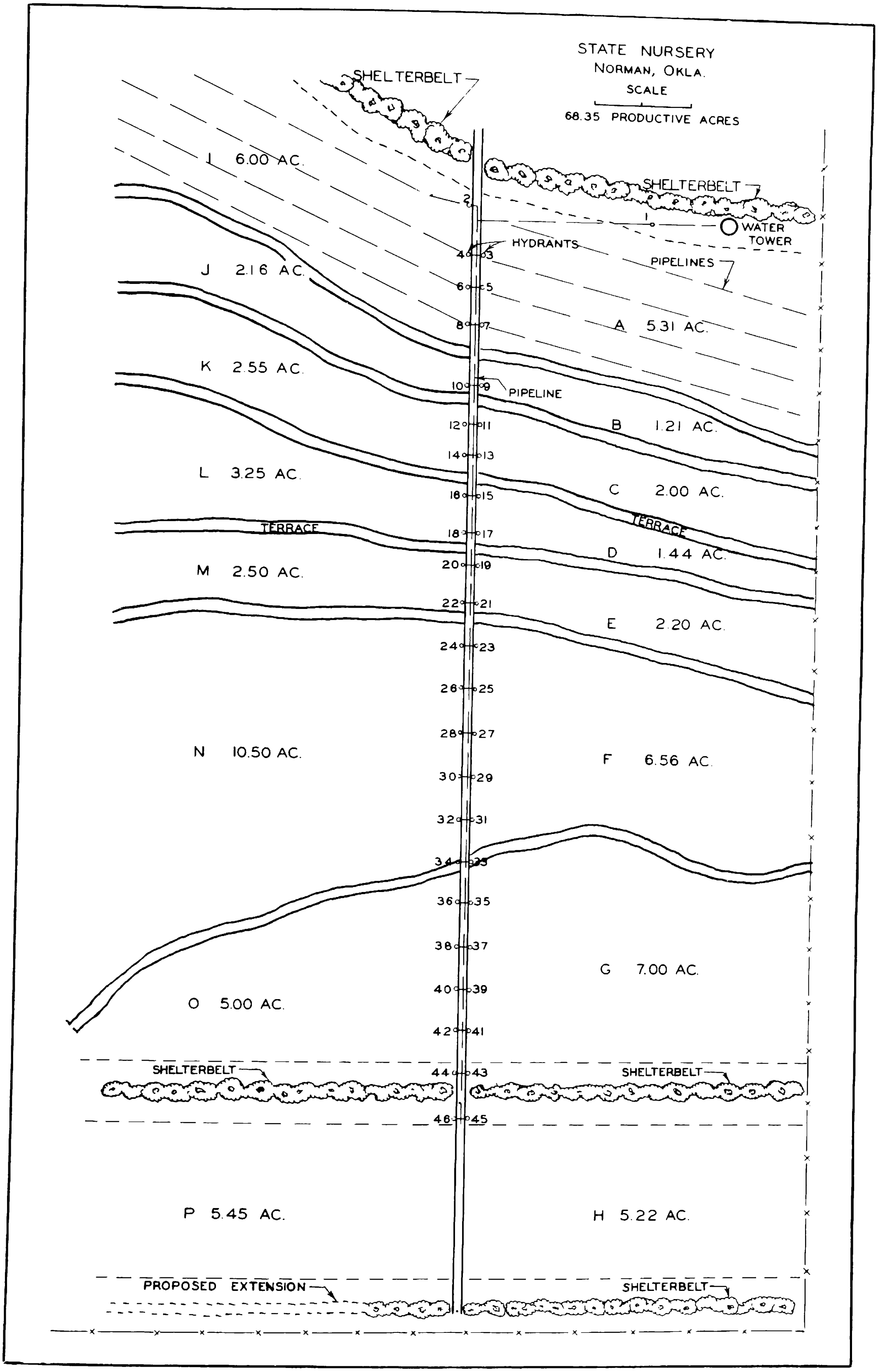

FIGURE 14.—Sprinkler irrigation system layout used at the Oklahoma State Nursery at Norman. Surface pipes of 4-inch diameter are laid on the contour between terraces from hydrants. The main pipeline is 8 inches in diameter.

water use, and leaching of soil nutrients. Also, flood irrigation is less apt to produce the fine fibrous root system desired on pines.

Under some circumstances, flood or furrow irrigation may be a convenient means of watering transplant beds or second-year seedbeds. Straight rows are preferred to contour rows because of the greater ease of layout.

SEEDBED PREPARATION AND SOWING

Ordinary farm equipment—tractors, plows, disks, and harrows—is used to prepare the soil for seedbeds, transplant beds, or cover crops. The choice of equipment will depend on the size of the nursery, comparative costs, and the personal preference of the nurseryman.

Both wheel and crawler-type tractors are used in Plains nurseries. The heavy jobs in the larger nursery will require a tractor of about 35-drawbar horsepower. A light unit of 15 to 18 hp. is suitable for the lighter jobs or as the basic power unit for the small nursery. Tractors equipped to use two- or three-point suspension implements are more maneuverable and versatile.

Rotary tillers are used at a few Prairie-Plains nurseries for ground preparation. They do an excellent job of incorporating manure, peat, and compost into the soil. However, they tend to pulverize the soil too finely, leaving it more subject to wind erosion.

As part of soil preparation, small patches of weed pests such as quackgrass can be spaded out carefully by hand, or eliminated by repeated use of a potato digger, quacker, or rotary tiller (Clifford 1934). If a rotary tiller is used, the hinged rear cover is folded so as to throw soil and roots a maximum distance. After use of any of the three machines, the roots are raked and picked off the surface. Especially heavy patches of quackgrass or other noxious weeds can be eliminated by use of chemicals such as methyl bromide, ammonium trichloracetate, or sodium trichloracetate. The manufacturers' instructions should be followed carefully. Sources of information on nursery machinery, equipment, and chemicals are given in the Appendix.

STAKING OUT AND PREPARING THE BEDS

After the seedbed area has been worked down and leveled, 4-foot-wide beds are staked out. Where overhead irrigation is to be used, 10 beds usually are spaced between the pipelines. The space next to the pipeline is usually 18 inches wide, and the nine paths between the 10 beds are 12 inches wide. Some nurseries use only nine beds in order to allow more path width. Stakes are set at each end of the bed, and binder twine is stretched between them to maintain alinement.

The final fitting of seedbeds is done by one of several methods. The object is to secure a smooth, slightly crowned, or flat bed. The paths are usually made a few inches lower than the bed centers. Mechanized equipment has superseded hand methods, reducing manpower requirements per unit of land prepared for seeding. A commercial seedbed shaper (Story 1940), or some adaptation of it (fig. 16), is used at the larger nurseries.

A method suitable for small-scale operations involves the placement along each bed of two 1- by 4-inch bedboards spaced 44 inches apart inside. The bedboards are held down with inverted U-shaped strap iron stakes (Robbins 1935, Stoeckeler and Jones 1957). The bedboards serve as a track on which to slide the bed leveler (fig. 17a). The simple device consists of a piece of 1- by 8-inch board 43 inches long; a piece of 2- by 4-inch wood about 2 feet longer than the 1- by 4-inch leveling blade is placed on both sides of the board. To reduce wear on the leveler, a steelplate is placed on the bottom of the leveler where it rides on the 1- by 4-inch bedboard. Once beds have been sown, dry, sandy nursery soil is sifted over them, and they are again leveled, with an adjustment for varying the depth of seed covering.

Seedbeds may also be prepared with a smoother,

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FIGURE 16.—A tractor-mounted bed shaper which forms and levels a seedbed in one operation. Bessey Nursery, Halsey, Nebr.

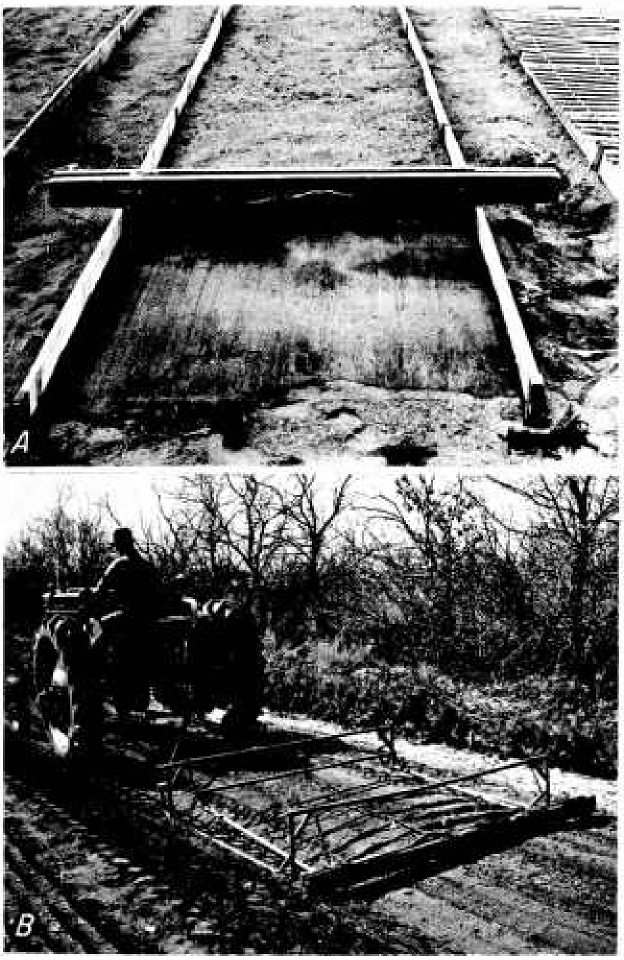

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FIGURE 17.—Two methods of seedbed preparation: *A*, a simple and effective float suitable for use on 1- by 4-inch bedboards; *B*, a seedbed smoother in operation.

(Futrell 1959) or a 4-foot-wide drag (fig. 17b). Drill seeding is done directly on this prepared bed.

In all bed preparation some hand touchup of the beds is necessary. The surface of small spots which has become excessively smooth or "shiny" is slightly roughened with push brooms or springy-tined leaf rakes just before seeding so that light seed will remain in place after broadcasting and before the seed covering is applied.

In some nurseries rollers are used to firm the seedbeds prior to sowing; other nurseries depend on the walking done on the beds while they are being smoothed, raked, or leveled. Rollers are also used to press the seed lightly into the soil after the beds have been seeded and covered. In large nurseries where seeding has been mechanized into one operation in which only one machine is used, the roller has been made an integral part of the seed drill.

COMPUTING THE AMOUNT OF SEED TO SOW

Seed should be sown on the basis of a specific weight of seed per unit of area to secure desired seedbed densities and to prevent seed wastage. Laboratory tests should be used to determine the germination percent. For freshly collected seed such as juniper, which may have to be fall-sown in the same season it is collected, a cutting test should be used to provide an estimate of quality.

The amount of seed to sow can be estimated by the following formula:

$$P=\frac{A \times D}{G \times S \times Y}$$

where P = pounds of seed;
A = area in square feet;
D = desired density in number of seedlings per square foot;
G = germination percentage of the seed, expressed as a decimal;
S = number of seeds per pound at time of seeding; and
Y = survival factor expressed as a decimal.

The survival factor (Y) is the percentage of the viable seed that survives to the transplantable seedling stage, whether that be the 1–0, 2–0, or 3–0 age. It varies greatly by species and nursery and drops with increasing age of the seedling (table 5). The survival factor can be determined only after data are obtained from germination tests, cutting tests, sowing rate tests, and bed inventories.

Seedbed density has a marked effect on stock quality, seedling size, cull percent, and efficient use of seed. It can be varied so that the maximum number of trees suitable for transplanting or direct field planting are produced. The experience and judgment of many nurserymen indicate that pine and juniper seedlings to be transplanted should be grown in broadcast-sown beds at a density of 50 trees per square foot, and that spruce intended for transplanting (2–0 and 3–0) should be grown at densities of not more than 100 trees per square foot. For drilled spruce seed the density can be reduced to 60 to 75 trees per square foot. In some of the Southern Plains States, conifers shipped from the nursery are fieldplanted as seedling stock, usually as 2–0. Such trees are grown at a density of 30 per square foot.

Fifty years ago Pearson (1914) recommended seedbed densities for ponderosa pine of about 75 per square foot. Higgins (1928) evaluated the seedbed density of ponderosa pine in terms of the lowest cost per surviving 2–1 tree in the field. He favored a seedbed density of 75 trees or less per square foot (table 6). Wahlenberg (1929) studied ponderosa pine under a range of densities from 80 to 275 trees per square foot and found 80 to be best. The stem diameter decreased 0.1 millimeter for each 44-tree increase per square foot. After

TABLE 5.—*Survival ratios for several species and age classes of stock at two Plains nurseries*

Species	Towner Nursery		Mandan Nursery[1]	
	1–0	2–0	1–0	2–0
Blue spruce	0.43	0.39	0.50	0.30
Ponderosa pine	.73	.63	.68	.60
Rocky Mountain juniper	.70	.62	.53	.50
Scotch pine	.57	.45	....	....

[1] Formerly operated by the Soil Conservation Service.

2 years in the field, the stock planted as 2–0 had a 1-percent decrease in field survival for every 15-tree increase in seedbed density. Current practice is to sow for 50 pine trees per square foot.

The number of 1–0 seedlings that survive in relation to the number of seeds that germinate also is influenced by seedbed density. Higher tree survival factors are obtained when medium-to-low seeding densities are used. In an experiment at Towner, N. Dak., with ponderosa pine, a medium seeding density of 112 seeds per square foot resulted in a 66-percent survival of 1–0 seedlings (fig. 18).

TABLE 6.—*Nursery performance, and second-year field survival and cost of 2–1 ponderosa pine as affected by nursery seedbed densities*

Trees per square foot of seedbed (number)	Average weight per tree	Nursery cull	Survival in transplant bed	Second-year field survival of transplants	Final cost of 1,000 surviving trees
	Grams	*Percent*	*Percent*	*Percent*	*Dollars*
76	3.98	5.4	89	75	4.48
95	3.88	7.5	88	67	5.05
121	2.88	9.4	88	62	5.52
141	2.60	11.1	85	61	5.62

TIME OF SEEDING

The time of year to seed conifers depends on the tree species, growth rate, and, to some extent, nursery location.

Seed dormancy and optimum germination temperature vary by species. Species having seed with embryo dormancy or a combination of embryo dormancy and impermeable seedcoat are fall sown, or they may be spring sown if the seed is first subjected to cold stratification. Those with impermeable seedcoats but no embryo dormancy are preferably spring sown after the prescribed pretreatment for rendering the seedcoat permeable.

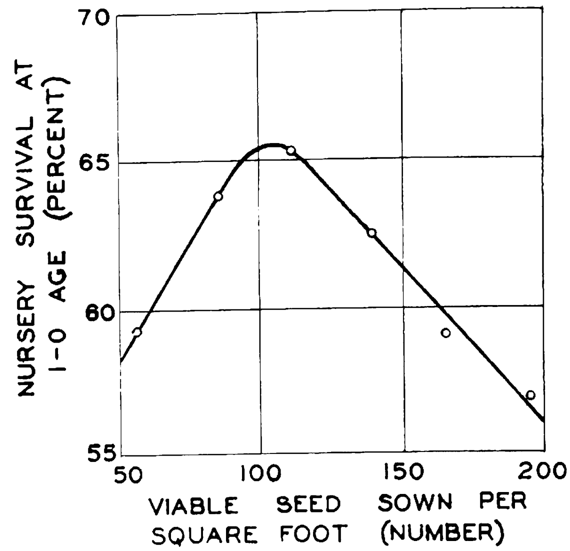

FIGURE 18.—Relation of first-year survival percent in ponderosa pine seedbeds to amount of viable seed sown per square foot. Towner Nursery, Towner, N. Dak.

Because of the longer growing season available to them, fall-sown seedlings commonly are larger and better developed at the end of the first season than are spring-sown seedlings. This differential growth of fall- and spring-sown beds can be used to produce seedlings of the desired size for field planting or for transplanting.

Local climate must also be considered in setting the time of seeding, particularly for fall sowing. Premature germination, with subsequent freezing and mortality of seedlings, can be avoided by delaying seeding to a time when unseasonable warm temperatures are less apt to occur. Coverings with insulating qualities, such as clean straw or marsh hay, can be applied to fall- and spring-sown beds to delay germination in the spring. With the above reservation, spring seeding should be done as early as the ground can be worked to allow the seedlings the maximum growing period.

Emergency late-season seeding (early summer) subjects the seedlings to high air and ground temperatures during germination and early growth, and frequently results in high mortality.

Eastern redcedar is sown in the fall after pretreatment. Seed of the current year depulped and cleaned with a lye solution usually germinates promptly the following spring. Rocky Mountain juniper is handled similarly but with less consistent results.

Most pine seed is sown in the spring. This is the general practice for ponderosa pine throughout the Plains. Promptly germinating species, such as jack, Scotch, shortleaf, Japanese red, and Japanese black pines, are also spring sown. Sometimes, to even out the nursery workload, ponderosa pines and other pines are fall sown. White pines, such as limber pine or Swiss stone pine, should be sown in the fall; if stratified seed is used, they should be sown in the spring.

Ponderosa pine in some Dakota nurseries is too small for transplanting as 1–0 and somewhat too large as 2–0. By delaying the seeding to about the first half of June, a 1½–0 tree about the right size for transplanting is produced. Such summer seedings must be watched carefully to avoid heat injury to the tender seedlings in midsummer. They may require not only shading but also more frequent light sprinklings to reduce soil surface temperatures. Summer seedings of ponderosa pine have also been used at the Bessey Nursery.

Spruce seed of dormant lots should be sown in the fall. However, if the seed are nondormant or stratified, they may be sown in the spring. In North Dakota [9] and Wisconsin (Jones 1934), white spruce seed sown in the fall germinates more promptly and completely than that sown in the spring.

BROADCAST VERSUS DRILL SOWING

Drill sowing has generally replaced broadcast seeding by hand in Plains nurseries, since it is more economical. It eliminates the cost of sand covering and permits mechanical cultivation.

However, broadcast seeding results in a more uniform distribution of seed, better mutual protection of seedlings, quicker formation of a complete ground cover, and more rapid suppression of weeds (Arnold 1956, Meines 1939). Brewster and Larsen (1925) found a 20-percent higher stand in broadcast beds than in drill-sown beds of ponderosa pine, both sown with equal amounts of seed.

At the Towner Nursery, in a controlled experiment, no significant difference was found between the two seeding methods in ponderosa pine beds grown at an average density of 59 trees per square foot. The average tree percent, based on viable seed sown, was 95.1 for drill-sown beds and 86.4 for broadcast-sown beds. At the 2–0 stage it was 66.2 and 65.6, respectively; the average fresh weight of 30 trees was 24.3 and 26.3 grams, respectively. All drill sowing was done by hand at carefully regulated seeding depths (fig. 19).

Spruces generally are regarded as better suited to the broadcast-sown beds than the usual drill sowings, since the depth of cover can be controlled more closely for broadcast seed. However, the best of the machine drill sowing should approach the control obtained by the hand method.

Research has shown no clear-cut advantage for either method in the quality and quantity of seedling stands produced, and the choice by the nurseryman will doubtless be influenced more by other considerations, such as the area of seedbed to be sown and equipment available for seeding.

SEEDING EQUIPMENT

Seeding, except on small-scale operations, is done with mechanical seeders which place the seed in rows

[9] Personal communication with John Molberg, Associate State Forester, Bottineau, N. Dak.

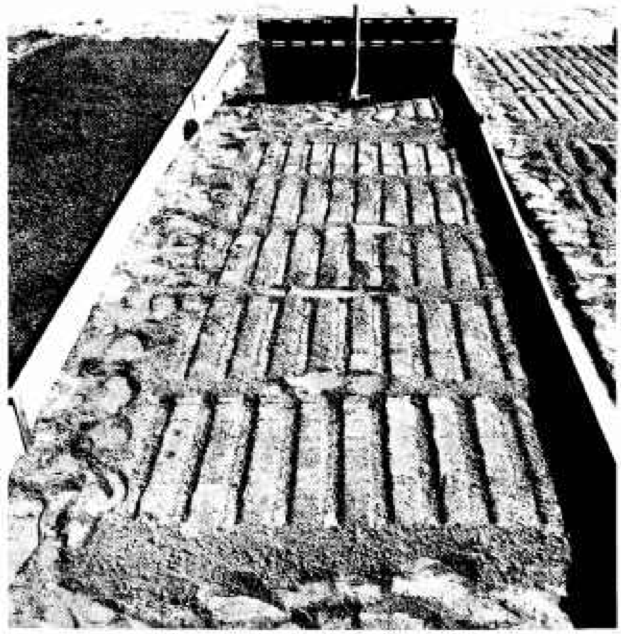

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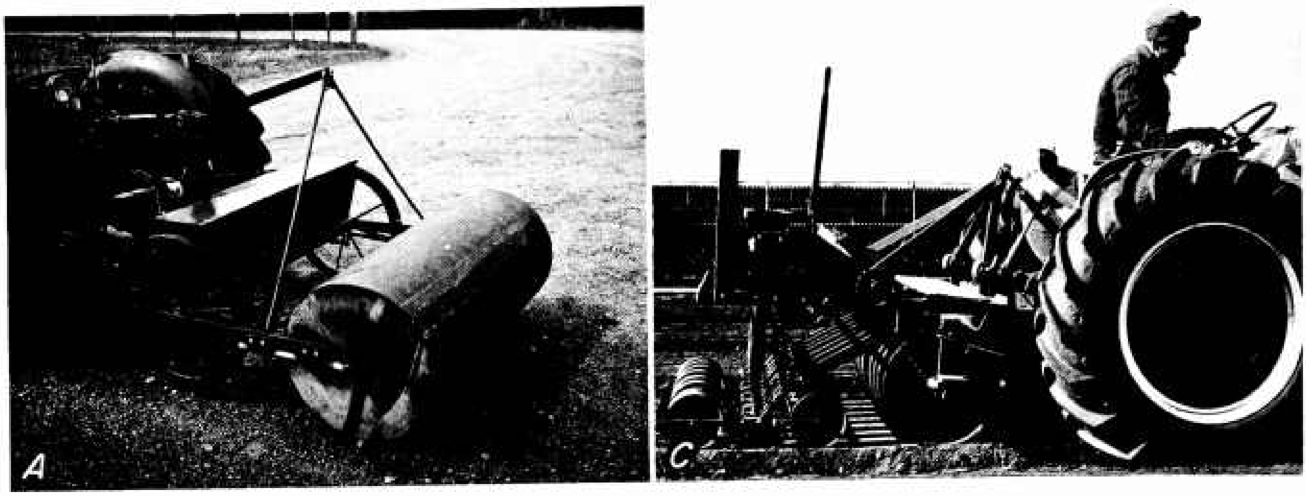
FIGURE 19.—Two- by four-foot experimental beds after use of hand method of drill seeding. The drills were made by tamping the 10-cleat frame in the background into a level, newly prepared, loose, moderately moist bed. The cleats are three-fourths by 1 inch. Seed is covered by hand or with the back of a rake drawn parallel to the drills.

or broadcast over the seedbed. Some seeders are manufactured commercially (fig. 20, *A* and *C*), while others may be built in a nursery shop from individual grain drill units assembled in batteries of 7 to 10 drills per 4-foot-wide bed (fig. 20*B*).

A lawn seeder is sometimes used. It is simply a V-shaped trough with adjustable openings in the bottom, which feed out the seed at a specific rate. A shaft rotor in the bottom is turned by the forward motion of the seeder and keeps the seed stirred up and feeding properly. The seed is covered by a mechanical sander. The seeder broadcasts seed over a full 4-foot-wide bed, and can successfully handle seed as small as white spruce (200,000 per pound) and seed sown to obtain 75 trees per square foot.[10] This seeder is especially suitable to small nurseries with a production of a few hundred thousand trees or less per year.

A second type of seeder, one with a 10-spout seeder, can be used for drill seeding (if equipped with 10 individual drill openers and closers), or can be adapted to broadcast seeding by letting the seed drop on a baffleboard placed at approximately a 45-degree angle to make the seeds bounce and slide toward the back, as the seeder is pulled forward (fig. 20*B*). It may be hand drawn or pulled by tractor. The seeder may run

[10] Personal communication with Robert Heintz, formerly Nursery Superintendent, North Dakota State Nursery, Towner, N. Dak.



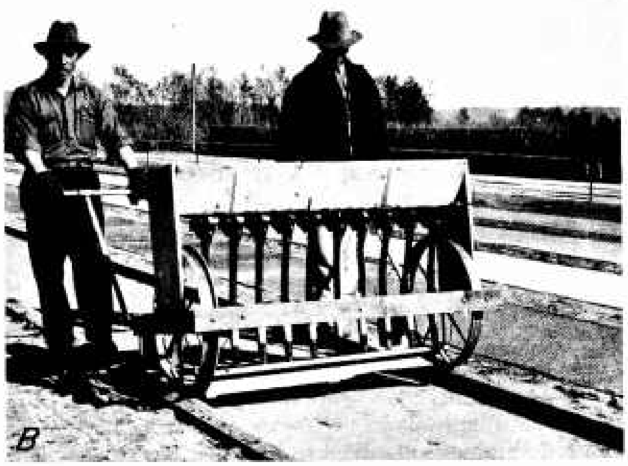


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FIGURE 20.—Several types of seeding machines suitable for 4-foot-wide conifer beds: *A*, A seeder used in combination with a roller; *B*, modified grain drill with 10 tubes, here used for broadcast seeding; *C*, eight-drill seeder-roller combination, Big Sioux Conifer Nursery, Watertown, S. Dak. *C*, (Courtesy of S. Dak. Dept. of Game, Fish, and Parks.)

on wooden tracks or on the smoothed soil of the seedbed path.

Seeders that sow and cover the seed in one operation are more commonly used than the preceding types. These sow the seed in drills the length of the bed. One or two flat rollers are incorporated (fig. 20*C*); these perform the final smoothing and firming of the seedbed and drive the seeding apparatus. The seed is fed from a common hopper through modified grain-seeding tubes to the seeding assemblies. Each assembly consists of an adjustable furrow-opening shoe and a furrow coverer. Packing wheels firm the soil in each drill row, before and after seeding.

On another type of seeder, two corrugated rollers are mounted rigidly in tandem, with one slightly offset from the other. The seed is fed into the sharply defined furrows formed by the first roller. It is then covered by the action of the second roller, which splits the ridges formed by the first roller.

All seeders can and must be adjusted to put out a specific number of seeds per square or lineal foot of drill. The usual procedure is to lay down a large canvas and, after making an approximate adjustment, to draw the seeder over it for a specific distance; the amount of seed laid down per unit of area is then counted and weighed. Adjustments are made until, after a few trials, the right amount of seed is laid down. The seeder is then ready to sow that specific lot of seed. Frequent checking is needed as seeding proceeds to make sure that each drill is feeding, that no refuse is clogging the feeding mechanism, and that the seed hopper or hoppers have enough seed to maintain a uniform flow.

COVERING THE SEED

After the seed is sown, a uniform depth of covering is needed for even germination of seed and a uniform stand of seedlings. Deep sowing makes emergence more difficult and increases the possibility of injury from damping-off fungi.

The proper sowing depth depends upon seed size, soil texture, and the season of sowing. The common practice is to sow the seed of the larger seeded species such as ponderosa pine at a depth of one-fourth to one-half inch and that of the finer seeded species at one-eighth to three-sixteenths inch. The seeding depth can be about one-third greater in the light sandy soils than in the heavier loam soils because of the greater ease of seedling emergence in the sandy soils. Seeds should be sown slightly deeper in the fall than in the spring to insure adequate covering of the seed in beds exposed to frost action and wind erosion.

The sowing depth recommended for ponderosa pine is supported by research. Show (1917) found that one-half inch cover was quite satisfactory. Brewster and Larsen (1925) found that on comparable plots under northern Rocky Mountain conditions, the number of seedlings obtained according to cover depth was as follows: one-fourth inch, 680; three-eighths inch, 650; one-half inch, 600; three-fourths inch, 550; and 1 inch, 470.

Trials at the Towner Nursery in North Dakota, in a considerably drier area than mentioned by the above investigators, showed the germination of ponderosa pine to be dependent both on depth of seeding and whether burlap mulch was used (fig. 21). Two seed lots of different germinative energy were used. The best stands with both seed collections were obtained with one-fourth to five-eighths inch depth and a burlap mulch. At three-fourths inch and deeper, the stand count for seed with a burlap mulch dropped very rapidly. Apparently under burlap, surface drying of beds is not as severe as in unmulched beds, and a very thin soil or sand cover suffices. However, when no burlap mulch was used, one-fourth inch proved too shallow a cover, and the unmulched seed in a considerable range of sand depth (three-eighths to three-fourths inch) gave better stands.

Managers of Prairie-Plains nurseries on sandy soils generally use drill seeding and thus avoid the need to cover the seed in a separate operation. However, in nurseries located on heavier soils there are excellent reasons for using broadcast seeding with peat, sand, or sawdust as a seed covering to avoid crusting. Straw mulches have been used in some nurseries, but one-fourth inch of sawdust was reported to be more effective (Clifford 1955, Knight 1958); it has the advantages of being free of weed seeds and not requiring removal (Allison and Anderson 1951). Whatever covering is used, seed that is broadcast sown should be pressed slightly into the soil with a roller before covering.

Sand to be used as a cover should be thoroughly tested to see that it is at least slightly acid. The test is made with a few drops of 10 to 20 percent hydrochloric acid. If the material fizzes, the sand is not desirable for use as a cover, since it is likely to increase damping-off disease.

Sands that are acid or neutral in reaction are scarce in the Great Plains, especially in the western part. Sands from subsurface layers of soil, which are more free of weeds and disease, tend to be even more alkaline in reaction. Some dune sands in the Plains may be leached of carbonates to a depth of 4 to 6 feet; these are suitable as seedbed covers. In areas of extensive heavy soils, sometimes the only suitable sandy material is in the surface 6 to 10 inches of the sandiest field that can be found.

Where no acid sands are within easy hauling distance of the nursery, Davis (1940) suggests that in lieu of using alkaline sands, the nurseryman drill sow, surface sow with burlap mulch, or broadcast sow with sawdust as a seed cover.

If straw or any type of hay is used, it should be as free as possible from weed seed. If such material is hard to obtain, the nurseryman could well grow some rye or oats in the nursery and mow it before seed has formed in order to assure a supply of mulch free from weed seed (fig. 22).

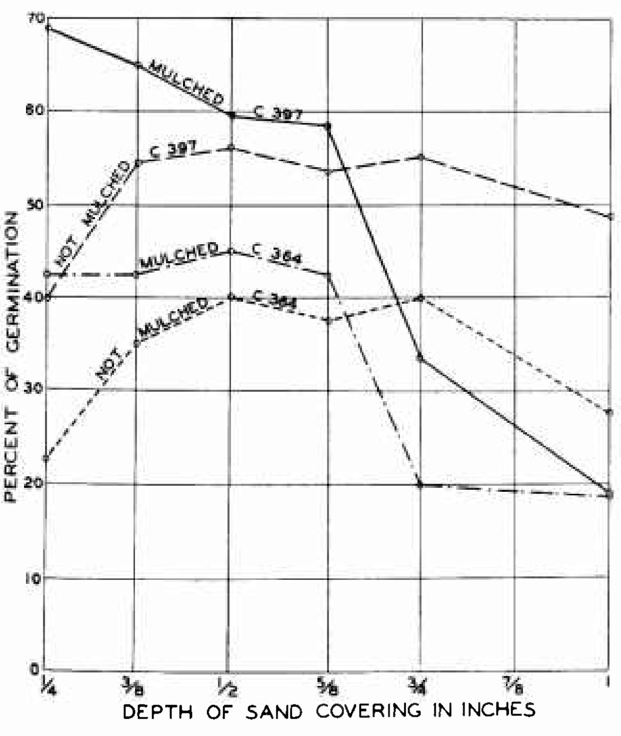

FIGURE 21.—The effect of depth of covering and use of burlap mulch on the germination of ponderosa pine seed, Towner Nursery, Towner, N. Dak. Two seed collection lots were used; the numbers on the trend lines designate these lots.

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FIGURE 22.—Application of a layer of straw on top of cotton commodity cloth in fall-sown beds, Bessey Nursery, Halsey, Nebr.

Mulch applied to fall-sown beds serves the following purposes:

1. It conserves moisture and reduces soil drying and cracking.
2. It prevents fall germination by reducing soil temperatures at seeding depth.
3. It retains soil temperature in the 33° to 50° F. range longer, and by preventing soil freezing in late fall or early winter, it provides a longer period of afterripening under conditions similar to controlled temperature stratification.
4. It reduces soil blowing and uncovering or deep burial of seed.
5. It prevents early spring germination.

At least one commercially manufactured sand spreader is available for use on broadcast-sown beds. However, most nurseries use homemade devices. A simple one consists merely of a frame, 2½ by 3 feet, with the long sides extending a foot or more beyond each end to make the handles. The bottom of the frame is covered by ¼-inch-mesh galvanized hardware cloth. Sand or sandy soil from the paths is shoveled onto the screen, which is shaken by two men.

A tractor-drawn endless-belt sand spreader was devised by Olson (1930). Bull (1954) describes a reciprocating sifter, suitable for sifting sand or sawdust, which is actuated by a camshaft and mounted on a trailer (fig. 23). The Savenac Nursery has devised an automatic trough sander, which is towed behind a dump truck from which the sand drops into the sander.

Any chemical treatments with liquid materials, such as acidification with dilute sulphuric acid or aluminum sulphate or postseeding weed-control drenches, should be applied after the seed is covered with sand or soil and before the burlap or any other mulch is applied.

F–505892

FIGURE 23.—A reciprocating sifter, Towner Nursery, Towner, N. Dak.

F–502093

FIGURE 24.—Pinning down burlap on newly seeded beds to conserve moisture and assure prompt, uniform germination, Bessey Nursery, Halsey, Nebr. Burlap covering also prevents wind erosion. Looped pins of galvanized iron wire are preferred, as they can be re-used.

Newly seeded beds are commonly protected with covers between seeding and germination. Soil moisture levels favorable for germination can be maintained with less watering. Use of burlap has been quite successful with the more rapidly germinating pines, especially in spring seedings (fig. 24). More recently, polyethylene film has been employed as a bed covering; it has an outstanding ability to virtually preclude any moisture loss from the beds. Burlap alone does not do this well, especially on fall sowings. A combination of polyethylene film covered by burlap prevents tearing of the film by wind and, by reducing soil freezing, increases the time the fall-sown seed is exposed to the beneficial afterripening effect of soil temperatures in the 33° to 50° F. range.

The life of burlap is extended by treating it with copper naphthenate (Anderson and Kineer 1949). After use, it should be dried thoroughly, beaten to remove excessive soil, and rolled for storage. A special burlap reel can be used advantageously (Stoeckeler and Jones 1957).

Five stages of nursery operation, including preparing the seedbed, seeding, rolling, seed covering, and sifting sand, are illustrated in figure 25. The methods shown represent an intermediate stage of development of nursery equipment that gave an accuracy of depth control in seeding seldom achieved by the more mechanized methods now commonly used, especially in the larger nurseries.

SEEDBED CARE DURING GERMINATION AND THE SEEDLING STAGE

The seed germination stage of about 10 to 30 days is most critical because the tender seedlings are easily injured. Mulches must be removed in the spring after the danger of killing frosts has passed. If allowed to remain in place until germination is well advanced and after the seedcoats appear above ground, the mulch interferes with early growth, and its removal from the bed is accompanied by mechanical damage. Great care must be used in taking up burlap or in raking straw mulches from the seedbed. Fiber or wire-tined rakes are less damaging than ordinary garden rakes. Complete removal is desirable since losses of seedlings are apt to occur as a result of excessive moisture and the root rot disease favored by the decomposition of the mulch.

HALF-SHADE

Half-shade is needed in Prairie-Plains conifer beds, particularly by the more delicate and smaller seedlings during the first season. It is common practice to shade all species except ponderosa pine and occasionally Austrian pine. These two species are more heat resistant and are often grown without shade. Half-shade prevents heat and drought injury, reduces water use, and minimizes soil drying (Hartley 1918, Stoeckeler and Jones 1957, Toumey and Korstian 1942). When placed directly on bedboards, it also excludes rabbits and dogs. Any half-shade tends to confine the intrusion of larger mammals, such as deer, to the paths.

Four separate experiments at the Towner Nursery showed that no advantage was to be obtained by shading ponderosa pine during the first year. The trends, when analyzed separately for each experiment, were nonsignificant statistically, but the stands, as noted below, were consistently greater in the unshaded beds.

Experiment	*Plots* [1] *Number*	*No shade (trees per square foot)*	*Half-shade (trees per square foot)*
A	48	78.9	75.1
B	64	54.6	46.0
C	64	61.2	57.2
D	32	52.2	45.8
Average		61.7	56.0

[1] Size of plots: A, 4 by 12 feet; B, C, and D, 2 by 4 feet.

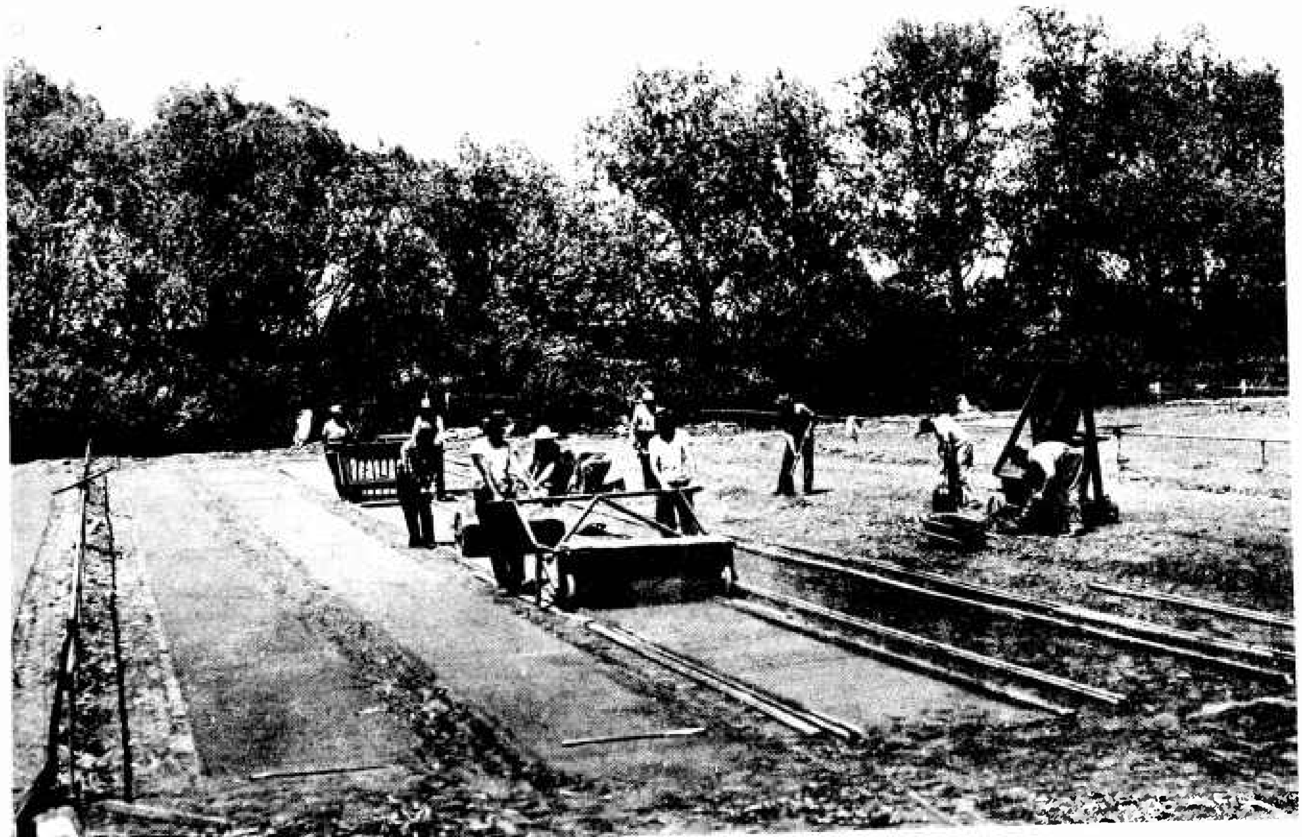

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FIGURE 25.—Various seedbed operations are illustrated here. Right background: preparing seedbeds and laying portable track. Center background: operating a 10-spout seeder, with seedbed roller following the seeder. Center foreground: operating a sanding machine. Right foreground: sifting sand with a slanting portable screen into sand-carrying tray.

Two experiments at the Towner Nursery compared the presence and absence of shade on the basis of tree percent of viable seed sown (fig. 26). Unshaded beds produced higher tree percents, except for high-density sowings in one of the studies.

Jack pine, however, does best under shade. In a study at the Towner Nursery, shaded beds consistently had a denser stand than unshaded beds and were substantially better at the higher rates of viable seed sown (fig. 27).

The advantages of shading are considered to be even greater with spruces than with jack pine, since the former are slower growing and more delicate than pine. Some nurserymen leave half-shade on second-year spruce until mid-September. The need for shade is somewhat dependent on the season of sowing and on watering frequency. Fall-sown seeds germinate more promptly than spring-sown ones. Trees, therefore, are larger and have thicker stems by early summer, and less heat injury occurs.

Almost all nurseries use slat-wire snow fence for half-shade. For high-shade, snow fence may be placed on two tightly drawn pieces of No. 9 wire supported on 30-inch posts driven into the ground with 1- by 2-inch crosspieces at intervals of about 12 feet (fig. 28). The snow fence is 12 to 20 inches above the ground. It must be wired together and drawn fairly taut at the ends. Some nurserymen take the additional precaution of attaching it to the No. 9 wire at intervals of about 25 to 30 feet to keep it from being thrown off the wires in high winds. If a third wire is run down the middle of the beds, upright supports can be at least 15 feet apart (Sharkey 1956).

Where bedboards are used, the snow fence is rolled directly on top of them. This lower shade is not quite as effective as higher shade because the strips of seedbed are exposed longer to full sunlight and there is less free air movement under the snow fence. Heat injury occurs occasionally when half-shade is positioned at a height of 4 or 6 inches.

A few nurseries use rigid shade frames. The Bessey Nursery, for example, uses individual 4- by 12-foot shade frames made of lath nailed to 2- by 2⅝-inch stringers—one on each long side. These shade frames are supported on each of the four corners by a piece of 1½-inch angle iron 3 inches long that has been welded to the top of a 22-inch-long five-eighths-inch bolt. The bolts are pushed into the ground about 6 inches.

SOIL MOISTURE AND IRRIGATION

The amount of water applied in a nursery will vary by water-holding capacity of the soil, annual precipitation, air temperature, humidity, wind, species, and age of stock. Each soil has a specific water-holding capacity, and only enough water need be added to raise it to field capacity. For sands, this value is about 8 to 12 percent; for loamy sands, 12 to 15 percent; for sandy loams, 15 to 25 percent; and for silt loams, 25 to 35 percent. Excessive watering tends to leach out soluble

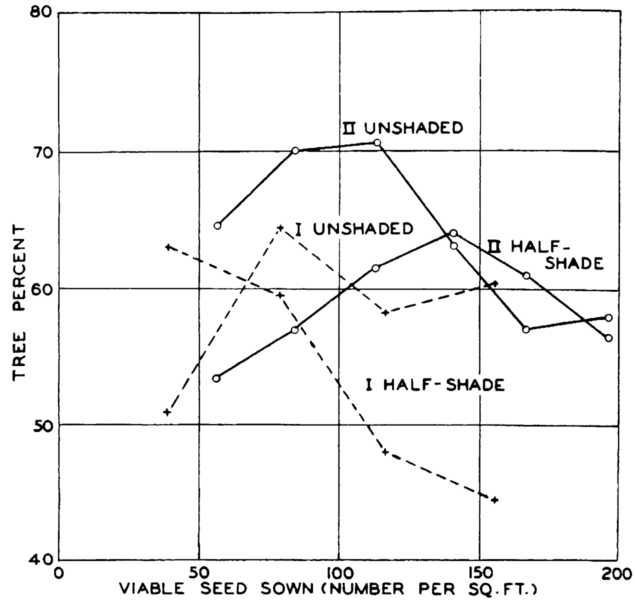

FIGURE 26.—Tree percent in 1–0 ponderosa pine beds in two separate experiments (I and II) in shaded versus unshaded beds over a range of sowing densities, Towner Nursery, Towner, N. Dak.

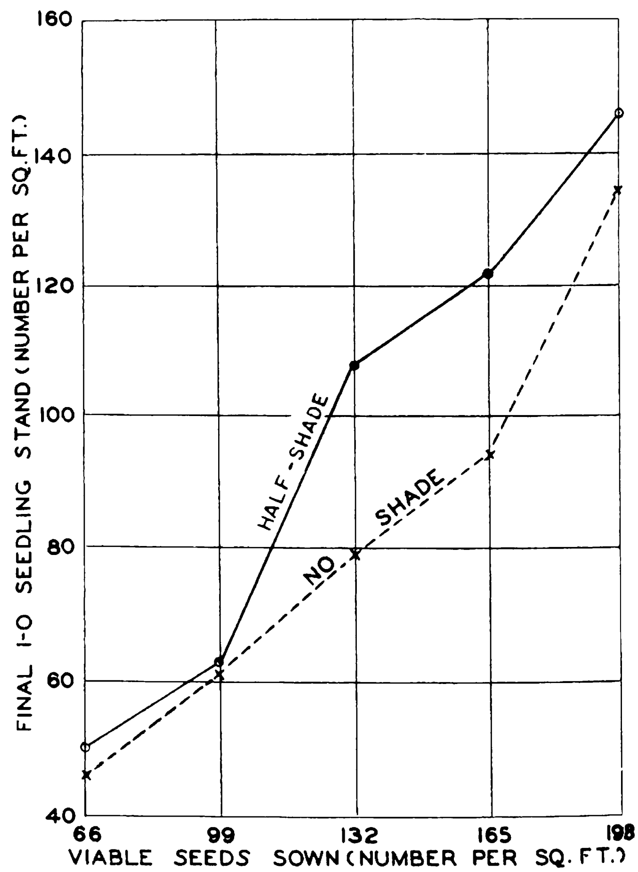

FIGURE 27.—Effect of half-shade on a stand of first-year jack pine seedlings over a range of sowing densities, Towner Nursery, Towner, N. Dak.

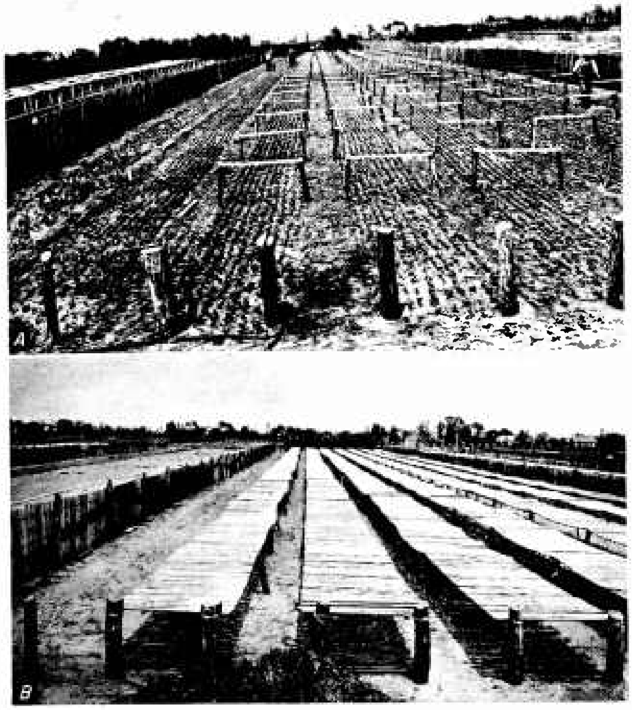

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FIGURE 28.—*A*, Round posts and crosspieces for half-shade support; *B*, the half-shade in position, Fremont Nursery, Fremont, Nebr.

nutrients, especially nitrogen and potash, and results in unnecessary use of water and power.

The amount of water to use on trees, particularly from midsummer on, or when the tree roots are at least 3 or 4 inches long, can be gaged by use of a tensiometer. This device consists of a porous ceramic cup fitted to a vertical aluminum or plastic tube to which is attached a sealed vacuum gage (fig. 29).

The entire system is filled with clean water, and the porous cup is buried in the soil in the rooting zone. Water moves through the porous cup to the soil until the tension or suction pull is equalized. The amount of pull is registered in the vacuum-gage dial pointer. The scale ranges from 1 to 100, and represents tension values from 0 to 1.0 atmosphere. Watering of beds is started as soon as the pointer gets into the 50 to 60 range. The tensiometer needs occasional filling with water. It may or may not be kept in one place, but about 8 hours must elapse before equilibrium is reached. Hence, it is desirable to have a tensiometer for first-year seedbeds, one for second-year beds, and another for transplants. If texture varies considerably, checks of moisture content must be made in several situations. Slight knolls that are exposed and very sandy soils will dry out faster than flat areas or those with a higher silt-plus-clay content (Stoeckeler and Aamodt 1940).

Soil moisture content can also be gaged by electrometric methods devised by Bouyoucos (1956) and Colman (1947), by oven drying or use of Livingston soil points (Stoeckeler 1939), or by the alcohol-burning method (Bouyoucos 1937).

Under nursery conditions, especially during active growth, soils should never be allowed to dry to the wilting point. Preferably they should have at least 2 to 3 percent of moisture in excess of the wilting point in sands and 4 to 5 percent in excess in sandy loams. Excessive soil dryness can weaken plants, while excessive watering tends to reduce drought resistance (Shirley and Meuli 1939, Stoeckeler 1951a). For example, where 2–0 jack pine were grown under four levels of watering in the nursery, optimum drought hardiness was achieved by those trees in seedbeds with an average available moisture content of about 5 percent from June 1 to September 15, or a total average soil moisture content of about 8.5 percent for a soil with a silt-plus-clay content of 10 to 12 percent (Stoeckeler 1951a). Among western species, Roeser (1940) determined that the water requirements of spruce and fir were considerably higher than those of ponderosa or limber pine.

Correct watering from germination to the time when root length is at least 3 or 4 inches and stems are moderately resistant to heat injury is difficult to gage instrumentally, and the nurseryman should rely on keeping the surface of the bed moist by light daily or twice daily watering. The ends of beds on the windward side may require hand watering with a hose. At the Bessey Nursery, first-year conifers are watered twice a day for the first 4 to 6 weeks; 0.15 inch is applied in the early morning and the same amount in the late afternoon. Thereafter, one watering is made per day, unless the beds are moist from rain.

Two-year-old stock requires watering about every 4

F–493114

FIGURE 29.—Two instruments for soil moisture determination. The soil mosture meter on the left works on the tensiometer principle; it measures comparative soil dryness in terms of suction pull of the soil. The moisture meter on the right gages soil moisture electrometrically by measuring resistance of current through buried gypsum blocks.

days, and transplants at least once a week; enough water is applied to soak the soil to an 8- to 10-inch depth. The amount required varies from 0.3 to 0.8 inch. In sand, 1 inch of water will wet the soil to a depth of about 1 foot (Woodward and Gilden 1955). The depth of wetting will depend on the soil moisture content when watering is started.

Near the end of the growing season, the trees are watered only once every week to 10 days to harden off the stock, reduce succulence, and increase frost hardiness. This hardening-off process begins in late August in the Northern Plains, in mid-September in the Central Plains, and in late September or early October in the Southern Plains.

WEED CONTROL

Weeds are a constant problem in nurseries and must be systematically eliminated by hand picking, by the use of hand-pushed or power-operated cultivators, or by the application of chemicals. Many nurseries use all of these methods.

Mechanical and Hand Weeding

In new seedbeds hand weeding is often used as a mopup operation after chemical weed control. Weeders may work in pairs on the same 4-foot-wide beds, each taking half the bed and working systematically from one end to the other, or each may have an assigned unit, consisting of one-fourth or one-half the length of the bed. The weeds are pulled by hand and dropped into boxes or collected later from piles in the paths. Deep-rooted, hard-to-pull, or persistent weeds, or those that break off, are dug out or cut off 1 inch or more underground with a steel cutter fixed into a loop attached to a wooden handle (Engstrom and Stoeckeler 1941), an old table knife bent into an L-shape (Tennessee Valley Authority 1954), or a similar handtool. Paths are cleaned with a push hoe or with wide sweeps attached to a rubber-tired tractor.

After the trees are about 6 weeks old, seedbeds sown in drills with a 4½- to 6-inch space between drills can be cultivated with power-drawn rotary weeders (McDaniel 1954, Mony 1954, Stoeckeler and Jones 1957, and Umland 1946).

Transplants in rows spaced 10 inches or more apart are usually straddle cultivated by a battery of ordinary farm cultivator shovels mounted on a tractor. In this operation, all the rows in a 4-foot bed are cultivated simultaneously. Where the row spacing is uniform and wide enough to accommodate a rubber-tired tractor, the rows can be cleaned with multiple-row cultivators to minimize damage to the trees. In transplant beds, four to six cultivations a year are needed to keep the weeds down.

Weeding should start when the weeds are quite small. Weeds 1 to 2 inches tall are eradicated much more readily than larger ones, and minimum damage to trees occurs. To reduce root breakage, beds should be made reasonably moist before weeding.

Chemical Control of Weeds

Chemical weeding is used much less in Plains nurseries than elsewhere. Wider use could reduce stock costs. Chemicals used rather extensively for weed control in forested areas include mineral spirits, allyl alcohol, and methyl bromide. Other chemicals being tested show promise. The generally rapid advance in the use of chemicals to control agricultural weeds is bringing additional benefits to nursery practice.

Safety rules and precautions for handling, mixing, and applying chemicals are given in the Appendix. All nurserymen should be thoroughly familiar with these rules and should see that adequate precautions are taken when any chemicals are handled.

Mineral Spirits

Mineral spirits are petroleum products that are used as selective herbicides in many conifer nurseries (Robbins et al. 1947, Stoeckeler 1951b and 1952b, Wycoff 1954). When used in proper amounts, they kill small broadleaf weeds and grasses without harming the evergreens. They can be purchased from most bulk gasoline distributors.

Undiluted mineral spirits are applied with pressure sprayers as a fine mist at a pressure of 50 to 100 pounds per square inch, generally at the rate of 25 to 75 gallons per acre (table 7). On a small scale they can be applied with a 1- or 2-gallon pressure sprayer. They are most effective if applied three to six times per season when the weeds are small, preferably about one-fourth to 1 inch tall. Taller and older weeds are more resistant to oil sprays.

TABLE 7.—*Dosages of mineral spirits used on conifer species in the north-central Prairie-Plains*

Species	Age		
	3 to 6 weeks	6 weeks to 1 year	1 year and older
	Gal./acre	*Gal./acre*	*Gal./acre*
Juniper, Rocky Mountain	25	30	40–60
Pines:			
Austrian	25	30	40–60
Jack	40	50	60
Ponderosa	25	30	40–75
Red	40	50	60
Scotch	40	50	60
Redcedar, eastern	25	30	40–60
Spruce:			
Blue	25	30	40
White	30	50	60
White (Black Hills)	25	30	40

The mineral spirits must be applied as a fine mist, and at a dosage reasonably near the optimum for the specific age class and species. The temperature at the time of spraying is also important. In the absence of specific information from Plains nurseries, it is recommended that application should not be made when air temperature exceeds 80° F., a limit that has been found safe in Lake States nurseries. Trials conducted over a period of years have helped to determine effective applications at individual nurseries.

Mineral spirits were first used in the Bessey Nursery in June 1948. They were applied with a Bean sprayer at 200 pounds pressure, using about 50 to 80 gallons per acre on seedlings and 80 to 115 gallons per acre on transplants. Weed kill ranged from 50 to 100 percent.

Good kill was obtained on lamb's quarters, primrose, barnyard grass, crabgrass, foxtail, sandbur, fescue, and pigweed. The following species were rather resistant to the spray: Panic grass, rye, ragweed, pepper grass, sunflower, nightshade, sage verbena, plantain, clover, and wood sorrel.

By 1951, dosages as low as 25 to 50 gallons per acre, sprayed when weeds were quite small (usually less than 1 inch tall), were giving up to 90 percent weed kill. These lower dosages reduced weeding costs 35 percent. Injury to seedlings was generally small, although occasionally about 5 percent of the trees showed some temporary yellowing that usually disappeared within 1 month. Mortality has been under 1 percent, or less than that normally lost in ordinary hand weeding and machine cultivation.

Seedlings less than 6 weeks old are more subject to injury from mineral spirit sprays, and special precaution must be taken with them.

At the Oklahoma State Nursery, excellent weed control has been obtained by application of mineral spirits two or three times a season in amounts as low as 12 to 15 gallons per acre. The mineral spirits were applied as soon as the secondary foliage appeared on the seedlings. Eastern redcedar and Austrian, ponderosa, shortleaf, and loblolly pines are among the species sprayed.

If weeds have emerged but the tree seedlings have not, excellent control with complete safety may be obtained by spraying the weeds with 50 to 60 gallons per acre of mineral spirits.

Methyl Bromide

Methyl bromide is a gas injected under polyethylene film or gasproof cover before seeding. Developed for disease control in forest tree nurseries, it has been very effective as a weed control on seedbeds in which first-year seedlings are produced. It has virtually eliminated all weed growth for 22 days or more after the tree seed has been sown (Stoeckeler 1951c). In the usual treatment, 1 pound per 100 square feet of bed area is used; however, the dosage may vary from one-fourth to 1¼ pounds, depending on the kind and severity of weed infestation and the soil texture (Mony 1961). In tests at the Towner Nursery in North Dakota, one-half pound applications reduced weed numbers by two-thirds, a degree of control equal to that obtained with dosages of 1 to 1¼ pounds. Air temperatures should range between 50° and 80° F., and a high moisture content of the weed seeds is essential for control.

Total costs, which include those for labor, gas, and plastic covers with a 2-year life, have averaged $234 per acre in Indiana. This was 67 percent of the cost of other chemical methods and 50 percent of the cost of solvent oil and sulfuric acid methods (Mony 1961).

Allyl Alcohol

Allyl alcohol has had excellent effect as a preseeding treatment when applied about a week before seeding. Also, no covers are needed. It can be applied at the rate of about 10 gallons of the concentrated chemical in 5,000 gallons of water per acre (Maki and Allen 1952, Steavenson 1952, Stoeckeler et al. 1951). Experience in Plains nurseries is lacking. In small-scale operations, it has been applied in 0.2 percent solution by volume with sprinkler cans or acid sprayers. On large-scale operations, the safest method appears to be that of Lanquist (1951), who injects a 10-percent mixture by volume of allyl alcohol in water through the riser end of the overhead irrigation system. The mixture is injected at the rate of 50 gallons per 400 feet of pipeline; watering is then used to obtain further penetration into the soil.

Miscellaneous Chemicals

Zinc sulfate (Wahlenberg 1930) has been used as a postseeding drench, at 8 grams per 250 cubic centimeters of water per square foot of seedbed, and has given 80 percent weed reductions. However, some chemical injury has been reported in dry seasons or during water shortages; spruce has been especially affected (DeJarnette 1936). Sulfuric acid has given good weed control, and it is considered safer than zinc sulfate, because of the possibility of zinc toxicity.

A 4-percent solution of formaldehyde, at 1 gallon of solution per square yard, applied as a drench well before seeding, has given good weed and damping-off control (Holmes and Ivens 1952).

Simazine has been used successfully for weed control in Minnesota nurseries. Stadtherr and Coultas (1961) applied one-half to 1 pound per acre as a postemergent treatment to conifer seedbeds on a heavy loam soil. Application of 1 to 2 pounds per acre was used in the second year after transplanting. Two applications were made on the transplants, one in May and the other in mid-July to August. On sandy soils some injuries followed its application. This chemical may warrant small-scale trials under Prairie-Plains conditions.

Other chemicals reported successful as nursery weed controls are vapam, applied at one-half or 1 quart in 21 gallons of water per 100 square feet (Briscoe and Strichland 1956); ferbam, at 500 pounds per acre in 10,890 gallons of water (Allen 1952); and 2,4-D, at 6 pounds per acre, as a preseeding or preplanting control (Clifford 1952).

POSSIBLE HARMFUL EFFECTS OF CHEMICALS ON TREES AND SOIL

In recent years chemical corporations and research chemists have developed scores of new chemicals for weed, insect, and disease control. Overdoses of these chemicals or their cumulative effects may adversely affect tree stand, tree growth, or beneficial soil organisms (Gambrell and Heit 1952, Theigs 1955, Voigt 1953, Wilde and Persidsky 1956). The nurseryman is advised to use conservative dosages found by repeated trials to be entirely safe for the crop he is growing. Manufacturers' recommendations should be checked at State and Federal experiment stations.

If experiments are undertaken with chemicals still being evaluated, only small areas should be treated. Usually application should be limited to a few hundred square feet in the form of small replicated plots. At Towner Nursery, monuron (3-(p-chlorophenyl)-1, 1-dimethylurea), used as a preseeding treatment in a weed-control experiment, was deleterious to eastern redcedar. There was a 60-percent kill of trees at 1 pound per acre, 80 percent at 2 pounds, and 95 percent at 3 pounds. Experiments must be repeated for several years on areas of different soil textures since weather and soil moisture content affect the action of some chemicals.

A good point to remember is that organic matter in the soil has a counteracting effect on the harmful action of many biocides (Voigt 1955).

TRANSPLANTING

Transplanting is a standard practice in almost all Great Plains conifer nurseries. Its primary purposes are to produce more fibrous root systems, thicker, sturdier stems, and better balance between roots and tops. More food is stored, the enlarged stems stand erect, and the more fibrous root system absorbs more moisture and food from the soil. Such plants often have 20 to 30 percent better survival than seedlings.

Transplanting usually is done when the seedlings are 3 to 5 inches tall. Some of the factors contributing to a good transplant job are good soil tilth, a smooth, level bed, and accurate and regular row alinement.

The method of lifting the seedlings for transplanting is the same as that for field planting. It is described under "Digging, Grading, Packing, Storing, and Shipping." After lifting, the roots are pruned, in small bunches, to a uniform length, usually about 6 inches. The trees are then placed in boxes, ready for transplanting.

Both hand and machine methods of transplanting have been used. The method depends on the size of the nursery, soil texture, amount of transplanting to be done, and the funds available for mechanization. Some of the hand methods have been highly efficient, and under some conditions the production rate has been exceeded very little by using transplant machines. Whether hand or machine planted, the trees should be watered thoroughly on the day on which they are transplanted.

HAND TRANSPLANTING

Hand transplanting is done across the beds in short rows or lengthwise in continuous rows 100 to 500 feet long.

Trenches are made in the soil with a hand or tractor-drawn trencher. A hand-trenching tool consists of two thin steelplates welded together, sharpened at the bottom, and fitted with galvanized iron handles (fig. 30*A*). Several nurserymen have modified small garden plows or pony plows so they will make a vertical-walled open trench for transplanting in long rows with the conventional transplant board (Jones 1925, Corson 1935).

The trenches should be deep enough and wide enough to accommodate the tree roots in a vertical

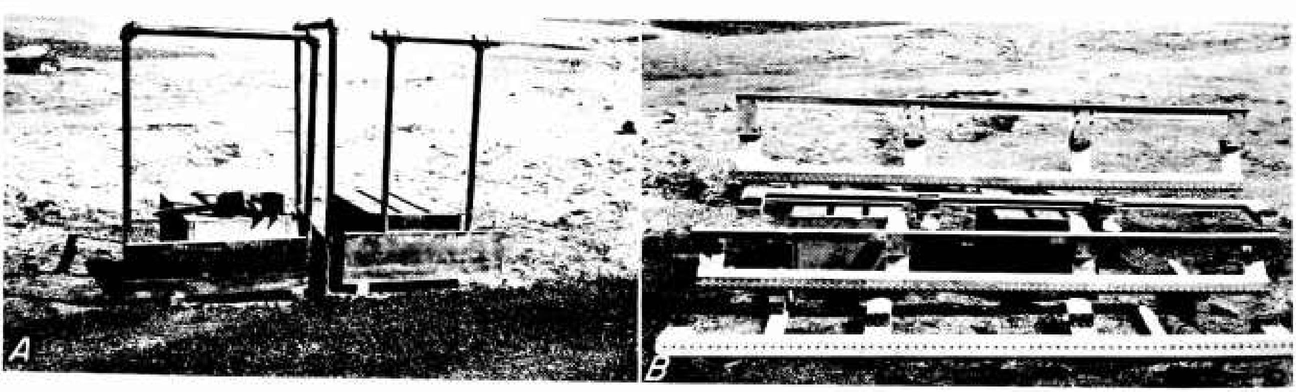

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FIGURE 30.—Equipment for hand transplanting: *A*, Hand trenchers formerly used at the Bessey Nursery; *B*, details of the construction of an aluminum transplant board.

position without curling. Crossbed trenches should be about 6 inches longer than the transplant board. The proper amount of soil moisture will prevent the sidewall from sloughing or caving in, in the interval between trenching and planting. Coarse, unrotted plant residues will interfere with the formation of a clean trench; hence, such materials should be plowed under early enough to decompose or should be removed from the site.

Seedlings are threaded into transplant boards with notches 1½ to 2 inches apart (fig. 30*B*) (Fox 1940, Olson 1930, Schrader 1938). To protect the plants they are threaded inside a light, portable shelter. A hinged upper clamp on the board swings down to hold the trees in place while the board is carried to a trench. The tree roots should always be kept moist. The roots will be less exposed if the walking distance from the shelter to the transplant bed is kept less than 50 feet by moving the transplant shelters frequently or by assigning short sections of bed (about 60 to 100 feet) to each planter if the rows are long.

In planting, the board is lowered with a swinging motion—to and fro—in the trench and parallel to it. After the roots are hanging vertically, the board is adjusted for depth so that the trees are planted one-fourth to one-half inch deeper than they were in the seedbed (fig. 31). The trench is closed with the feet or a tamper; looseness around the roots must be prevented. Heel marks and depressions are smoothed by adding loose soil between the transplant rows.

When long boards (8 to 10 feet) are used, the transplant area must be exceptionally smooth and level so that all trees are placed at the proper depth. With a 10-foot board with 80 notches at 1½ inches, Oliver (1937) reported that an average of 8,600 trees per 8-hour man-day were transplanted in hand trenches across the bed. Olson (1930) reported using an 8.5-foot board with 75 notches, but the planting was done the long way of the bed in an open, vertical-walled trench made with a small 7-inch horse-drawn plow. The crew average was 11,000 trees per man-day. DeJarnette and Augenstein (1946) produced 11,500 trees per man-day by the same method. Six two-man crews were used; a threader and planter worked in each row.

At the Bessey Nursery, hand transplanting in recent years has been done with a 6-foot-long board containing 60 notches. A 20-man crew was employed; it consisted of 10 threaders, 5 planters, 3 trenchers, 1 tree carrier, and 1 foreman. Trenching was done by hand across the bed with a mast trencher 26 inches wide. One trencherman worked in each group of five beds, while each planter confined his work to three beds, planting each trench as it was opened by the trenchermen. Planting coops, each with two threaders, were kept within about 50 feet of the transplanting work. The crew planted 150,000 to 175,000 trees per 8-hour day.

Recently, the Bessey Nursery has started transplanting the long way of the bed. Each bed has seven rows

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FIGURE 31.—Two methods of hand transplanting. *A*, Planting 1–0 eastern redcedar across the bed, using a board about 6 feet long; man in foreground is trenching and the man nearest him is firming the soil around the roots of the trees, Bessey Nursery, Halsey, Nebr. *B*, transplanting ponderosa pine in long, continuous trenches made by tractor-drawn trenchers; this method is well adapted to subsequent mechanical cultivation, Towner Nursery, Towner, N. Dak.

spaced 7 inches apart; thus, the standard lifter for 4-foot-wide seedbeds can also be used on transplant beds.

MECHANICAL TRANSPLANTING

Mechanical transplanting is accomplished with the Holland Seedling Transplanter, "New Idea" vegetable planter, or a similar type of machine. The so-called "mechanical transplanter" is not fully automatic. Each seedling must be handled individually and placed in a self-closing pocket on a revolving metal disk, or between two self-closing revolving disks. Normally two rows are transplanted at a time, but the number can be increased to seven (Hanks 1962) by mounting additional transplanting units on a special carriage (fig. 32).

The transplanting machine has many advantages; the chief asset is the elimination of the heavy manual labor involved in hand trenching and trench closing. Since mechanical trench opening and closing are combined in the same operation, the trench is left open to drying for an absolute minimum length of time.

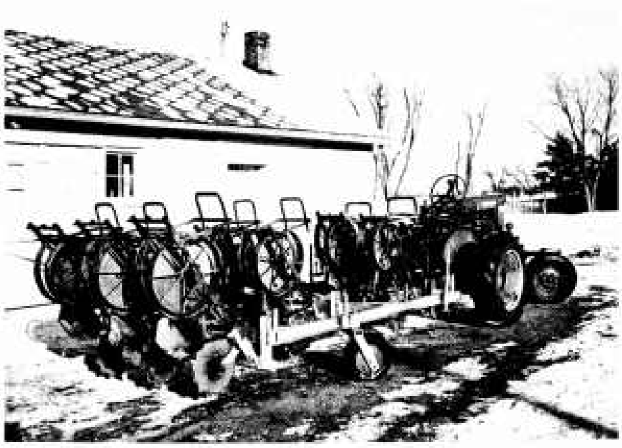

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FIGURE 32.—Seedling transplanter used to transplant seven rows at a 7-inch spacing in one operation. The method permits the lifting of seven rows at a time with the same lifter used for seedbeds. It also permits efficient mechanical cultivation of seven rows at a time by a bed-straddling tractor. Bessey Nursery, Halsey, Nebr.

The tree roots are exposed to the air much less than in hand transplanting, where no protection of the threaded boards being moved from the transplant coops to the planting trench is possible. Transplanting can be done by crews of women; they are more nimble fingered than men in feeding seedlings into the planter. When the transplanting machine is used, less training, teamwork, or balancing of crews is required for maximum efficiency. Furthermore, the machine is geared to a specific speed (usually about 11 feet per minute), and the planters must keep up.

The trees are set by the mechanical transplanters 1½ or 2¼ inches apart in the row. The wider spacing permits trees, especially 2–2 or large 2–1 stock, to be separated with a minimum of root stripping when they are lifted. Batteries of transplanters pulled by one power unit may transplant two to seven rows during one trip over the beds. Uniform spacing between rows is obtained; thus, the trees are less likely to be damaged during later cultivation.

Transplant machines usually set about 10,000 trees per person per 8-hour day. Thus, use of these machines results in production only equal to or a little greater than that obtained by use of some of the most efficient transplant-board methods already mentioned, particularly those where long trenches are made by horse- or tractor-drawn trenchers. Mechanical transplanting has been widely adopted by the nursery industry, largely because of a shortage of labor for hand transplanting.

TRANSPLANT SPACING

Spacing within the transplant rows of at least 1½ inches is desirable. This interval has been determined from spacing experiments and general observations on stock quality, ease of separating roots, and freedom from root stripping.

Janouch (1927), studying spacing in 2–1 jack pine and in 1–1 and 2–1 ponderosa pine, concluded that 6- by 1½-inch spacing at the Bessey Nursery was nearly ideal and that 6- by 2-inch spacing was slightly wider than needed. He based these conclusions on subsequent field survival of the stock.

A comprehensive study of transplant spacing was initiated in the Towner Nursery in the spring of 1939 by personnel of the Lake States Forest Experiment Station. The species involved were ponderosa pine and Rocky Mountain juniper. Four spacings within the row (1, 1½, 2, and 4 inches) and four spacings between rows (6, 12, 18, and 24 inches) were tried in all possible combinations.

A sample of juniper stock was lifted and measured after 1 year in the transplant bed (table 8). Based on a caliper limit of one-eighth inch for a plantable tree, a spacing of at least 6 by 1½ inches, or 9 square inches per tree, was necessary to yield a fairly high percentage of plantable stock. The 2-inch space between trees had a marked advantage over 1½-inch spacing when row spacing was 1 foot or less.

When the juniper stock was lifted at the 2–2 age, the maximum production of usable stock occurred at the 6- by 1-inch spacing. All spacings gave at least 75 percent plantable stock. The top-root ratio was a little high, generally 4.0 to 5.0, which is not as good as it was at the 2–1 stage. The largest percentage of premium stock (using caliper as a criterion) was produced at a spacing of at least 12 by 2 inches.

Considering all factors of cost and performance, there seems to be no need for growing 2–2 Rocky Mountain juniper at a spacing greater than 6 by 2 inches. The usual spacing attained by mechanical transplanters should produce uniformly good stock but with less efficiency than that obtained with closer spacing between rows.

The ponderosa pine in the spacing experiment were all grown to the 2–2 age (table 9). The stock measurements showed that 6- by 1½-inch spacing produced good-sized stock of adequate height and stem caliper. All of the trees were slightly more top heavy than was desirable because of exceptionally favorable growing conditions in the fourth year.

The percentage distribution by stem caliper for 2–2 stock of two conifer species is given in table 10. Apparently, if a considerable proportion of the trees are to have a stem caliper of one-fourth inch or more, spacings of about 6 by 2 inches or larger are necessary.

TRANSPLANT LOSSES

In transplant beds, some of the trees die despite careful handling. To compensate for these losses, the amount of stock transplanted must be increased.

At the Savenac Nursery in Montana, the loss in ponderosa pine has been 3.1 to 30.0 percent (Fox 1937, 1939; U.S. Forest Serv., Rocky Mountain Region 1931) and is generally 10 to 20 percent. In the Northern Prairie-Plains, junipers and redcedars have had

TABLE 8.—*Effect of transplant spacing on size and grade of 2–1 Rocky Mountain juniper, Towner Nursery, Towner, N. Dak. The transplanting was done in the spring of 1939 and trees were measured in the spring of 1940*

Spacing (inches)	Average length		Average stem diameter	Green weight		Usable stock [1]	Premium stock [2]
	Top	Root		Total	Top-root ratio		
	Inches	*Inches*	*64ths inch*	*Grams*		*Percent*	*Percent*
6 by 1	11.0	11.1	9	21	3.2	73	17
6 by 1½	9.3	10.9	11	22	2.8	97	47
6 by 2	12.5	11.0	15	34	3.2	100	86
6 by 4	9.5	9.5	14	28	3.0	100	77
12 by 1	10.1	9.6	11	18	3.3	90	33
12 by 1½	9.5	10.0	12	28	3.0	93	61
12 by 2	9.9	9.5	15	33	3.6	100	80
12 by 4	11.0	12.3	17	30	3.4	100	97
18 by 1	9.5	8.9	11	41	4.9	87	43
18 by 1½	11.6	10.2	14	58	3.6	100	73
18 by 2	10.9	11.0	14	36	3.9	97	70
18 by 4	10.8	9.3	18	46	3.8	100	93
24 by 1	12.1	12.0	13	29	3.6	93	57
24 by 1½	9.7	9.8	13	29	3.5	97	70
24 by 2	9.9	9.0	14	33	3.4	100	70
24 by 4	11.0	12.4	17	56	3.7	100	97

[1] Trees with a stem diameter of at least 8/64 inch.

[2] Trees with a stem diameter of at least 12/64 inch.

TABLE 9.—*Effect of transplant spacing on size and grade of 2–2 ponderosa pine, Towner Nursery, Towner, N. Dak. The transplanting was done in the spring of 1939 and trees were measured in the fall of 1940*

Spacing (inches)	Average length		Average stem diameter	Green weight		Usable stock [1]	Premium stock [2]
	Top	Root		Total	Top-root ratio		
	Inches	*Inches*	*64ths inch*	*Grams*		*Percent*	*Percent*
6 by 1	7.2	12.3	16	26	4.3	100	50
6 by 1½	9.0	12.2	18	37	5.2	80	65
6 by 2	7.9	13.3	18	38	5.2	100	90
6 by 4	9.3	13.3	21	63	5.4	100	85
12 by 1	10.3	12.3	15	22	4.1	90	25
12 by 1½	8.5	15.8	18	45	5.3	90	75
12 by 2	8.2	14.3	20	58	4.8	100	95
12 by 4	8.0	14.6	20	59	5.0	90	75
18 by 1	5.8	13.5	15	24	4.1	90	45
18 by 1½	8.0	14.7	16	32	5.3	95	55
18 by 2	7.9	16.8	19	57	4.9	85	55
18 by 4	10.2	15.1	23	94	5.9	100	88
24 by 1	8.5	15.1	19	49	4.1	100	90
24 by 1½	8.8	15.8	18	50	5.5	90	60
24 by 2	8.8	15.7	21	72	4.9	95	70
24 by 4	8.5	15.0	21	63	4.5	95	80

[1] Trees with a stem diameter of at least 8/64 inch.

[2] Trees with a stem diameter of at least 12/64 inch.

losses of 5 to 15 percent; and spruces, losses of 15 to 25 percent. At the Bessey Nursery in Nebraska, losses in the first-year transplant beds have been about 10 percent, with a usual range of about 4 to 15 percent.[11]

[11] Personal communication with M. K. Meines, Nurseryman, Halsey, Nebr.

Each nursery must develop an experience table (see table 11) of first-year transplant losses by species and age class since season of transplanting, method of transplanting, and other factors affecting survival vary considerably over the Prairie-Plains.

Transplant losses are minor after the first season in the beds.

TABLE 10.—*Percent of trees over a given caliper class in 2–2 juniper and 2–2 ponderosa pine*[1]

Spacing (inches)	2–2 juniper with a caliper of at least—			2–2 ponderosa pine with a caliper of at least—		
	4/32 inch	8/32 inch	12/32 inch	4/32 inch	8/32 inch	12/32 inch
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
6 by 1	97	30	1	92	41	3
6 by 1½	99	33	3	99	59	10
6 by 2	93	53	8	99	63	12
6 by 4	99	70	18	97	59	14
12 by 1	97	33	2	94	50	19
12 by 1½	97	49	5	100	62	23
12 by 2	100	54	9	97	69	21
12 by 4	99	88	40	100	79	46
18 by 1	98	48	13	87	44	9
18 by 1½	98	71	21	99	63	12
18 by 2	100	74	27	99	70	26
18 by 4	100	83	44	100	83	50
24 by 1	92	55	16	97	55	19
24 by 1½	99	53	11	96	53	12
24 by 2	98	58	13	99	74	31
24 by 4	100	84	47	100	84	36

[1] Based on 100 trees of each species in each spacing, or a total of 1,600 trees per species.

SEASON OF TRANSPLANTING

Transplanting is invariably done in the spring in the Prairie-Plains. Fall transplanting has been tried, but its use generally resulted in abnormally high losses, especially in the Northern Plains.

TABLE 11.—*Average first-year losses in transplants at the Bessey Nursery, Halsey, Nebr., 1943–1956*

Species	Age class	Average loss
	Years	*Percent*
Juniper:		
Eastern redcedar	1–1	4.4
Do	2–1	12.5
Rocky Mountain	1–1	11.5
Do	2–1	15.2
Pines:		
Austrian	2–1	10.1
Jack	2–1	14.9
Ponderosa	1–1	12.4
Do	2–1	7.4
Red	2–1	11.1
Spruce:		
Blue	2–1	6.1
White	2–1	8.7
Do	3–1	11.4

Trees should be transplanted as early in the season as possible to take maximum advantage of the growing season, especially when the trees are left in the transplant bed only 1 year. In the Dakotas, some transplanting has been done in late May and early June and has been successful, especially in producing ponderosa pine and juniper stock that was rather well balanced as 2–2 stock. It could more accurately be described as 2–1½ stock since it had only about 1½ growing seasons in the transplant bed.

TOP AND ROOT PRUNING

Top and root pruning are used in Prairie-Plains nurseries to retard excessive top growth and keep the trees in better balance. Some favorable results have been obtained, but there is insufficient information on which to make general recommendations. Root pruning of seedlings and transplants is also done in the beds prior to lifting as a preparation for transplanting or packing.

The survival of blue spruce of 2–2 or 3–2 age class undercut in the third week of April in the transplanting bed was 18 percent greater (range 4 to 27 percent) than that of unpruned stock.[12] The first-year field survival of the undercut stands was 94 to 100 percent. Ponderosa pine of 2–2 age undercut in the same series of tests had a survival of 100 percent, while the unpruned stock had a survival of 94 percent.

Undercutting of third-year Rocky Mountain juniper in the spring at Towner Nursery in North Dakota slightly improved the balance. Fairly fibrous root systems resulted from a strong stimulation in lateral rooting. Practically no roots formed at the point of root pruning.

To cut nursery production costs, root pruning of seedling stock in place has been recommended as a substitute for transplanting in areas of better rainfall (Foster 1932, Hastings 1923), but it has not been tested very much in the drier Prairie-Plains area. A special thin-bladed root pruner (Olson 1930, Stoeckeler and Jones 1957) or a lifter with the kicker prongs removed is used. Seedbeds are sometimes root pruned with a horizontal V-shaped steel blade. Bed margins bordering paths have been vertically pruned with 18-inch rolling coulters in drill-sown seedbeds in early June (Clifford 1956a). Two weeks later the entire bed was undercut by horizontal pruning.

At the Towner Nursery in North Dakota, top pruning of 3–0 ponderosa pine in June, while the new growth was still in a succulent stage, had an adverse effect. The unpruned trees had a first-year field survival of 49.2 percent, whereas that of the top-pruned trees was only 34.5 percent. A liquid fertilizer was applied to the trees in this test within a week or so after

[12] Personal communication with E. J. George, Agricultural Research Service Field Station, Mandan, N. Dak., Mar. 2, 1958.

pruning, a procedure found desirable in later top and root pruning experiments in the Lake States (Stoeckeler and Jones 1957).

Junipers seem more amenable to top pruning than pines. Rather substantial improvement in balance was obtained by top pruning 2–2 Rocky Mountain juniper at the Towner Nursery (table 12). The reduction of excessive top length by top pruning may improve the balance of juniper. But more specific information on the effects on field survival is needed before top pruning can be generally recommended for 2–2 Rocky Mountain juniper.

If this species becomes too large at the 2–2 age, as it does in some nurseries in the Dakotas, an alternative may be to grow 2–1 stock, assuming it gives high field survivals.

TABLE 12.—*Effect of three degrees of top pruning on size and top-root weight ratio of 2–2 Rocky Mountain juniper*

Degree of top pruning	Average length of top just after pruning	Measurements of 2–2 stock in fall						Top-root ratio
		Length		Stem diameter	Fresh weight per tree			
		Top	Root		Top	Root	Total	
	Inches	*Inches*	*Inches*	*64ths inch*	*Grams*	*Grams*	*Grams*	
None	....	14.0	10.6	13.8	29.41	8.87	38.28	3.32
Light	8.26	11.3	10.4	12.7	22.53	8.38	30.91	2.69
Severe	4.06	6.0	10.9	14.3	17.19	8.25	25.44	2.08

HARDENING-OFF

The hardening-off process prepares conifer stock for survival through the winter. It results from gradual exposure to temperatures that are about 32° F. (Harvey 1930, Levitt 1956). Physiological changes that increase cell sap concentration and reduce the succulence of young foliage protect the plants against sudden drops in temperature in late fall and from unseasonably warm winds in February and March. Hardening-off is encouraged by the reduction of the water supply and the removal of shade.

The cutting off or reduction of the water supply begins in late August in the Dakotas and in late September in the Southern Plains. Watering should be kept moderately low for 4 to 6 weeks thereafter. Excessive dryness, however, should be avoided. Sandy soils should not be allowed to dry below about 2 or 3 percent of available moisture.

Exposure to high light intensity accentuates the color change in eastern redcedar; color change is generally regarded as a visual criterion of hardening and formation of anthocyanins (McDermott and Fletcher 1955). The removal of half-shades will accentuate and advance fall coloration (fig. 33).

Certain species and age classes, notably 1–0 ponderosa pine, 1–0 and 2–0 jack pine, 1–0 Scotch pine, 1–0 lodgepole pine, and 1–0 eastern redcedar, have a marked color change in the fall—from green to purple, violet, or bronze (Büsse 1930, Dengler 1944, Kalela 1937, Kienitz 1922, Langlet 1936, Stoeckeler and Rudolf 1956). The color change, part of the normal hardening-off process, occurs from late September to early November, depending on the nursery location. It is especially striking in pine nursery stock grown from seed of colder or more northern latitudes (Stoeckeler and Jones 1957) than that of stock grown from seed of warmer or more southern areas. In one

F–475107

FIGURE 33.—Half-shade is rolled up in early September and left in paths until late October to harden-off the stock. It is then replaced to give overwinter protection. Towner Nursery, Towner, N. Dak.

study the degree of color change in jack pine showed a statistically high correlation with latitude and average January temperature of the seed source (Stoeckeler and Rudolf 1956). The abnormal color disappears during the next growing season, with little apparent effect on the plant.

DIGGING, GRADING, PACKING, STORING, AND SHIPPING

When nursery stock is ready to be outplanted or sold, its value is a result of all the direct and indirect costs that have accrued during the time required to produce it. Therefore, the digging, grading, and packing of trees must be supervised closely to assure healthy, uninjured stock when it is fieldplanted. In addition, the rapid completion of these operations permits earlier shipments to planters and an earlier resumption of other seasonal nursery operations. Some storage of the packed stock is inevitable, and facilities must be provided.

DIGGING NURSERY STOCK

Nursery stock lifters are of two general types (fig. 34). One type can be applied to the entire width of the bed at one time. It may be used for seedbeds or transplants. The lifter blade for undercutting a bed may be mounted on a sled or attached directly to the tractor. A lifter mounted hydraulically to the tractor is readily transported from place to place. The second type of lifter is the U-shaped digger used for transplants in rows. It is usually mounted in pairs on a Unicarrier frame.

Several elaborate lifter designs have appeared in recent years. These include (1) the agitating lifter of the Savenac Nursery, designed to remove some of the soil from the roots (Sowash 1954), (2) the Lanquist seedling harvester, which includes an endless belt on the lifter onto which counted trees are dropped in bundles (Lanquist 1954a), (3) a hydraulically operated lifter mounted on the back of a crawler tractor (Cossitt 1937), and (4) a modified two-row potato digger devised by Clifford (1956b) for lifting 2–0, 3–0, and 2–2 stock.

At the Bessey Nursery, production of an eight-man crew is 250,000 seedlings in an 8-hour day; four men pull, one packs, two carry trees to the baler, and one works on the tractor lifter. A foreman directs the operation.[13]

A day or two before lifting, beds should be watered. Watering reduces root breakage and rapid drying of the undercut beds or rows. The bed-type of lifter is generally dug in at the end of the bed before the power is applied. The lifter is run at a depth of about 7 inches for stock to be transplanted and at about 9 inches for stock to be fieldplanted. As the seedlings or transplants are loosened by the digger, the labor crews pull the trees upward in bunches and shake the roots to remove surplus soil (fig. 35). Stock should be grasped well down around the stems and in small enough bunches to avoid injuring or stripping the needles and roots.

The importance of exposing roots of trees as little as possible has been repeatedly emphasized (Briggs 1939, Cummings 1942, Haasis 1914, Stoeckeler and Jones 1957, Toumey and Korstian 1942, Wakeley 1954). Conifers are particularly sensitive, and as little as 5 minutes' exposure of Jeffrey pine has reduced field survival by 10 percent, and 10 minutes' exposure by 15 percent. Every 10-minute period thereafter, field survival was reduced by about 10 percent. At

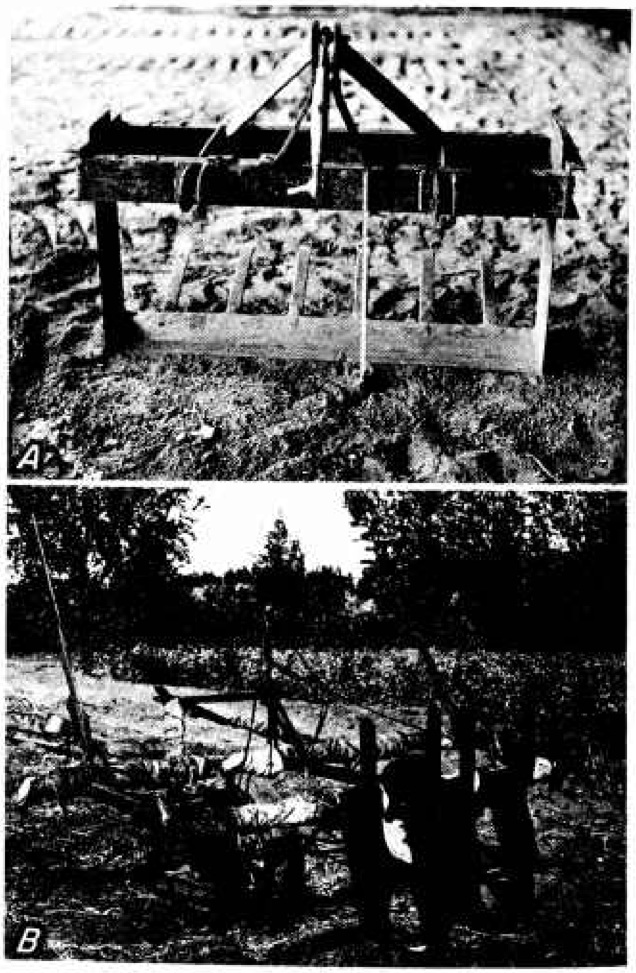

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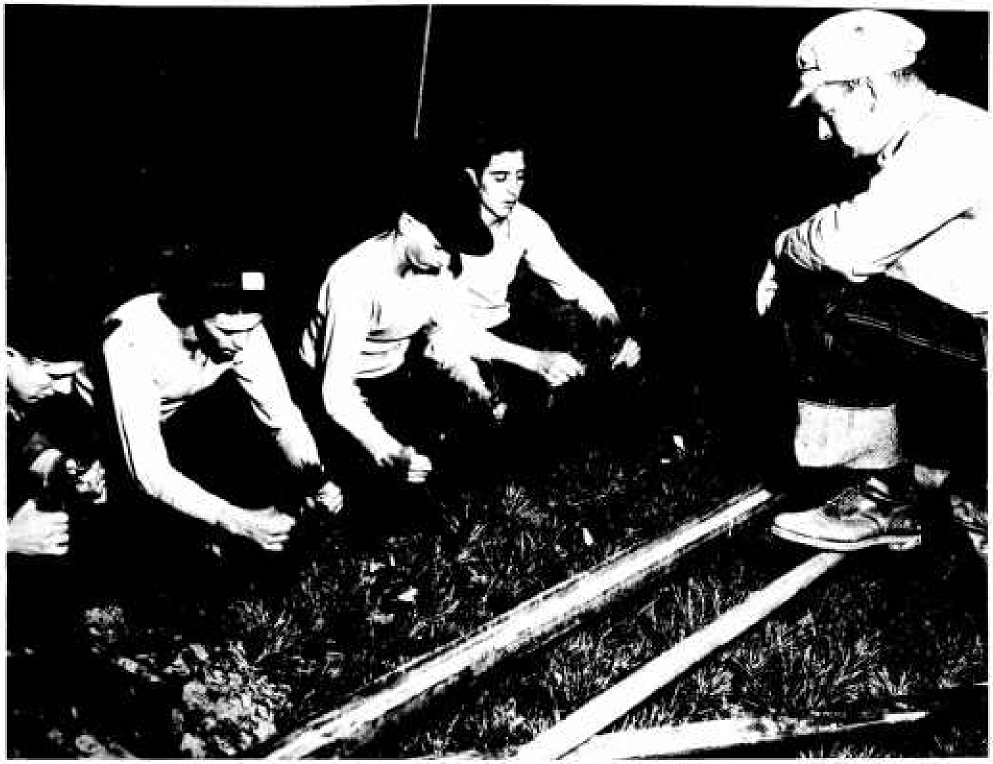
FIGURE 34.—Two types of tree lifters: *A*, Details of the Bessey Nursery seedling digger revised from the Smith tree lifter and used for 4-foot-wide beds. *B*, a two-row lifter mounted on a Unicarrier chassis, used for transplants lined out in long rows. Note burlap wrapping to reduce skinning of trees.

[13] Personal communication with M. K. Meines, Nursery Superintendent, Bessey Nursery, Halsey, Nebr.



F–502094

FIGURE 35.—Lifting 1–1 ponderosa pine transplants with a Smith tree lifter, Bessey Nursery, Halsey, Nebr.

the end of 50 minutes of root exposure, field survival was only about 15 percent (U.S. Forest Serv. Calif. Forest Expt. Sta. 1954). The rate of air movement, temperature, and relative humidity are important factors in the rate of root drying and subsequent damage. Hence, trees should be placed in boxes covered with wet burlap as promptly as possible and immediately transported to the grading and packing shed or shelter, to cold storage, or to crews doing transplanting.

Undercut beds tend to dry out fast, and trees should not be undercut more than a few hours before pulling. Work should be planned so that a minimum of unpulled undercut beds are left overnight or over the weekend. A light watering of the unpulled undercut beds with the overhead system may be desirable. Watering must not be so heavy as to cause substantial settling and repacking of the soil, or the pulling will be harder and more roots may be stripped.

Tree digging should be done as early in the spring as possible, while the trees are still reasonably dormant. A study at the Bessey Nursery in 1939 on the effect of early versus late lifting of eastern redcedar on first-year survival showed the serious disadvantage of late lifting:

Date of lifting [1]	*Survival of all trees*	*Survival of thrifty trees*
	Percent	*Percent*
March 31	74	57
April 28	33	22

[1] All trees were fieldplanted on May 5. Bessey Nursery 1939 Ann. Rpt.

Stock for field shipment is root pruned to a length of about 8 inches, stock for transplanting to 5 to 6 inches. In some nurseries, root pruning is done just after lifting and before the trees are placed in carrying boxes or trays. In other nurseries, it is done just before packing or transplanting. Pruning is done with a circular saw, meat cleaver, modified cleaver (Mony 1941), or a one-blade shear-type pruner with a stationary base similar to a paper trimmer (fig. 36).

GRADING

Grading nursery stock increases field survival and growth. It is especially important that the stock planted meets the grade specifications in areas where tree establishment is difficult to obtain. All nursery stock requires some grading to remove undersized and defective trees. This is done at the time of transplanting and when stock suitable for fieldplanting is lifted for shipment. Culls at the time of transplanting run about 10 to 15 percent. Discarded are the obvious runts; root-stripped, split, or skinned seedings; and diseased or insect-infested trees. Topheavy and oversized trees are also undesirable. In the grading operation, species mixtures resulting from mixed lots of seed can be separated.

Grading to remove undersized and damaged trees has consistently resulted in better survival and growth in the field (DeJarnette 1938, Fowells 1953, Read 1955).

F-502401

FIGURE 36.—The Savenac root trimmer in operation.

As early as 1910, Bates (1910) planted three grades of 2–1 ponderosa pine on the Nebraska National Forest and found first-year survival in the field to be 86, 73, and 65 percent, respectively, for large, medium, and small grades of stock.

In 1935, fieldplanting of 2–0 ponderosa pine of two size classes, made in 18-inch furrows on Valentine sand at the Denbigh Field Station near Denbigh, N. Dak., resulted in greater survival and height growth for large-grade stock. Of the 6,132 trees planted, 969 were of the small grade, which consisted of the poorest of the nursery-run stock. After 10 years in the field with no cultivation, 21.6 percent of the large-grade trees and 2.3 percent of the small trees survived. Average total heights were 2.4 and 1.3 feet, respectively.

Fowells (1953) found 10 to 11 percent greater survival of large grades of ponderosa pine after 9 years in the field. Ninth-year tree heights also were 12 and 18 percent greater for large grades of seedlings and transplants, respectively.

Undersized trees are culled out largely on the basis of stem caliper, although top length is sometimes used as well as root length and development. A caliper gage (Aamodt 1941, Barton 1940) is useful for training personnel in estimating stem diameter. It may consist of a Y-shaped piece of brass calibrated in diameter, a notch of a specific diameter cut into a wood or metal gage, or two pieces of steel welding rod spaced far enough apart on another rod to provide a fixed gage.

At the Towner Nursery, cull percent in transplants has been about as follows: 2–2 Rocky Mountain juniper, 15; 2–2 ponderosa pine, 10; 2–2 white spruce, 10; and 2–2 blue spruce, 2. In Oklahoma nurseries, cull percent in 2–0 seedlings of pine and eastern redcedar intended for fieldplanting is about 10 to 15 percent.

During the grading of stock, it is desirable to reduce the length of time and severity of conditions under which tree roots are exposed. Hence, the trees are generally moved indoors promptly and sorted. Sorting can be done efficiently on an endless belt marked in squares upon which exactly 10 trees are laid (Robbins 1942). Culls are dropped into boxes or onto the floor. A vegetable spray mist keeps the roots moist while they are on the belt. At the end of the belt, other workers pick off groups of 5 bunches and tie the stock in bundles of 50 with an electric bundle tier. Using this system, 8,200 trees can be lifted, graded, and tied per man-day.

PACKING

Trees are wrapped in burlap or waterproof asphaltic paper prior to shipment. They may be packed in a baler or rolled tight on a table. Cardboard containers often are used for parcel post shipments. Some crates are used.

With the Savenac tree baler (Olson 1930), two wires are placed in notches across the open end baling box (34 by 17½ by 15 inches deep on 20-inch legs), and two slats (1 by 2 by 24 inches) are laid at right angles to the wires. A strip of waterproof paper (1½ by 6 feet long) is laid over the wires. Some nurseries use 24-inch-wide burlap. Next, packing material is placed in a layer about 1½ inches deep, and a layer of trees is laid down, with the roots overlapped and the tops out toward each end of the baler. A layer of moss is laid down, and the process is repeated. After the baler is about half full, some moss is stuffed between the waterproof paper and trees at the two vertical walls of the baler so that no roots are in contact with the paper.

When the bale is completed and no roots are exposed, the two ends of the paper are held up and given enough turns around a third slat to take up all the slack.

The ends of the wire (Signode straps are sometimes used) are inserted into a Girard wire-tying machine, and two ties are made rather tightly to give a firm, compact bundle that will retain its shape, keep the moss in place, and not fall apart in subsequent shipment. Properly packed bales are barrel shaped and are about 18 inches in diameter (fig. 37).

The weight of the bundles and the number of trees each contains vary by species and age class and the packing material used. Weights and trees per bale of some species and age classes for the Bessey Nursery are listed below.

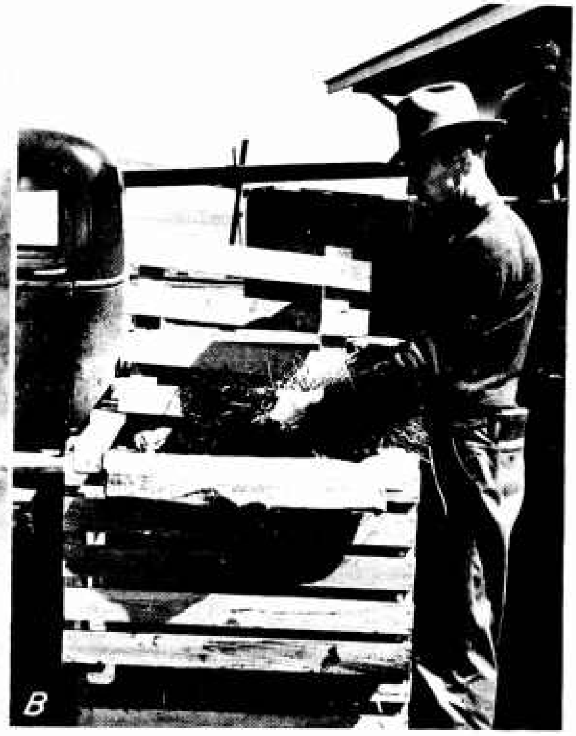


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FIGURE 37.—Two types of containers for shipping nursery stock: *A*, A packed bale being secured with a strapping machine as it lies in the tree baler, Bessey Nursery, Halsey, Nebr.; *B*, crates of the type used on the shelterbelt project, Towner Nursery, Towner, N. Dak.

Species	*Age class*	*Weight per bale* (*Pounds*)	*Trees per bale* (*Number*)
Austrian pine	2–2	83	800
Blue spruce	2–1–1	60	2, 000
Eastern redcedar	2–2	85	645
Do	1–2	63	500
Do	1–0	60	10, 250
Ponderosa pine	2–2	88	650
Do	1–2	98	2, 000
Do	2–0	71	4, 160
Rocky Mountain juniper	1–2	77	1, 000

In table wrapping, which is better for small orders, a sheet of waterproof asphaltic paper, about 30 inches wide and 4 to 8 feet long (depending on bundle size), is laid on the table. A 1-inch layer of packing material, about 18 inches wide and 24 inches long, is put on one-half of the sheet near its end, and counted bundles of trees are placed on the paper, with all roots overlapped toward the center. Successive layers of moss and trees are built up until the bundle is full enough to wrap. A layer of moss completely covers all trees, and the bundle is rolled as tightly as possible and tied with binder twine or stout cord in three places.

In another table wrapping method, all the roots are placed in one direction on the paper, with the layer of packing material toward one long edge of the paper. When rolled, the paper is folded over to enclose the bottom of the bundle, and tied twice around the circumference and once under the bottom.

Some cardboard boxes are used in parcel post and express shipments of bare-rooted conifers and potted grafts. The cardboard box shipments via parcel post are rather expensive, but the time in transit is minimized.

For Clarke-McNary shipments of stock by the State Forester in Nebraska, six standard box sizes are used:

Box number	*Dimensions in inches*
1A	4 by 4 by 30.
2	6 by 6 by 30.
3A	4 by 6 by 30.
4	6 by 10 by 30.
5	12 by 12 by 36.
6	10 by 10 by 30.

After assembly with 3-inch gummed paper, the boxes are lined with wax-coated freezer paper, which comes in rolls 18, 20, and 24 inches wide. The trees are packed with well-squeezed sphagnum moss. When trees are packed with 25 to the bundle, the roots usually are overlapped in the center of the box and the tops are out. The packages are then sealed and addressed, and 12 holes are punched in the ends of the long sides near the tops of the trees for ventilation. Postage, affixed at the nursery, generally costs about $0.40 per 100 trees, $0.80 per 200 trees, and $2.00 per 1,000 trees. The largest boxes can hold about 1,000 trees each of 2–0 eastern redcedar or 2–1 pines, or 400 to 500 trees of 1–2 eastern redcedar.

A few nurseries pack trees in light crates of wood slats or veneer. Crates are most likely to be useful if trucks haul the trees from the nursery directly to the tree-planting site and bring the empty crates back to the nursery daily or several times a week. In such instances, the trees need not be counted or tied in bundles; a bed inventory or a general knowledge of the average number of trees per crate is a sufficient basis on which to determine the approximately correct number of trees that should be supplied to field crews or fieldplanting machines.

Some commercial nurserymen are using plastic film bags and a small amount of moist moss or peat around the roots of bare-rooted conifers up to about 2 feet tall. The method has considerable merit, especially in retail yards where stock may be held for considerable periods.

The packing materials used for conifers usually are a 50–50 mixture by volume of sphagnum moss and cedar shingle tow (shavings). The material comes dry in bales from the supplier and must be mixed and soaked down before use. Some nurseries keep a vat of prewetted material in a cool, shaded place; it is used to supply 50-gallon drums alongside the baler or packing table.

The water in the drums should be cold and should be cooled with ice if necessary. Warm packing materials accelerate heating and molding of baled or crated stock (Stoeckeler and Jones 1957). Usually the water from deep wells (about 45° to 52° F.) will not require precooling. In some nurseries concrete moss tanks and slatted drainboards are fitted across the top of the tank.

Excess water must be squeezed out of the packing material before use, in order to prevent excessive weight and soggy bundles. It is particularly detrimental in parcel post shipments made in cardboard boxes.

A detailed study of various packing materials by Mullins (1956), in which stock was stored up to 4½ weeks, showed that there was little to choose between four materials, based on subsequent field survival. The materials were commercial sphagnum moss, freshly collected local sphagnum moss, poplar excelsior (wood wool), and poplar excelsior treated with a wetting agent.

STORING AND SHIPPING

The interval between lifting and planting should be minimized. For example, a prolonged period in transit and storage between lifting and planting is a primary cause of poor field survival in shelterbelts.

However, a delay after the trees are lifted from the nursery bed is not always avoidable. Normal irregularity in planting operations due to weather or other factors is almost certain to disrupt the flow of stock. Lifting often must be done before the frost is out of the ground at the planting site. A more serious problem occurs when the nursery is located far north of the planting site and lifting cannot begin until some time after planting is feasible. In some situations storage of planting stock may be necessary for a few days to several months.

The length of time permissible for storage depends on temperature, moisture conditions, packing material, species, and growing conditions subsequent to planting. Trees can be stored by three general methods: Heel-in storage, indoor storage at room temperature, and cold storage. Great care must be taken to prevent heating, molding, drying, high transpiration, hard-freezing, and damage by rodents and insects.

Stock in bales, crates, or cardboard containers may be stored indoors in a ventilated shelter for a few days (fig. 38). In cool weather, such storage is permissible for about a week. In warmer weather, when indoor temperatures in the storage shelter reach 70° F. or above, the trees can be stored in this way for only a day or two because heating and molding may occur.

Test plantings of 2–0 eastern redcedar in central and western Oklahoma, conducted to determine the effect of storage and season of planting on survival, showed that storage for an extra week in the packages in which they had arrived from the nursery had little, if any, effect on survival (Afanasiev et al. 1959). Plantings were made at four sites at weekly intervals from mid-November to May during three planting seasons.

Unbaled conifers have also been stored successfully indoors for several days to a week on a slat platform 6 to 8 inches above the floor (Engstrom 1941). One- or two-inch-mesh chicken wire is formed into a cylinder 18 inches in diameter and 4 feet high. A 3-inch layer of moist moss or other packing material is laid down, and the trees are placed on top of it, with the tops out and with the root ends just touching the wire. Alternate layers of moss and trees are built up to the height of the wire form. In warm weather a block of ice may be dropped on top of a 3-inch-deep layer of moss inside the chicken wire, and a board or other cover may be placed on top.

A modification of this system consists of platforms or racks 24 inches wide, with uprights at each end. Layers of trees are placed with tops out and roots overlapped; enough moss is used to keep the roots moist. Chipped or chunked ice can be placed on top to provide a cooling effect in warm weather.

At the Northern Great Plains Field Station of the Agricultural Research Service, at Mandan, N. Dak., stock is usually stored on the floor of a root cellar;

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FIGURE 38.—Stacked bales of 2–1 ponderosa pine in storage and ready for shipment by truck, Bessey Nursery, Halsey, Nebr.

individual tree bundles (not bales) are stacked upright in a single layer. Any larger air spaces below the tops are filled with moist packing material. With this method, survivals are reported to be 20 to 25 percent higher than they are with conventionally stacked horizontal storage.[14]

For periods longer than a week, cold storage is necessary. Many nurseries use mechanically refrigerated or ice-cooled cold-storage buildings. A temperature of 33° to 40° F. is preferred. At this range, respiration and transpiration are minimized, and heating and molding are prevented. A temperature of 50° is reasonably satisfactory. The humidity is maintained at about 90 to 95 percent. An average size cold-storage plant has a capacity of around 5,000 cubic feet and can hold 600,000 to 700,000 1–0 or 2–0 trees.

In the Dakotas, stock is often stored on natural ice in the spring. Partitioned-off areas in storage sheds are prepared by flooding and freezing during the winter. The stock is stored in mulch laid on the 4- to 6-inch layer of ice.

Stock has been held in cold storage for long periods with little or no drop in field survival (Brown 1937, Deffenbacher and Wright 1954, Fowells and Schubert 1953, Pike 1933, Sowash 1936).

Heel-in storage should be regarded as a last resort for conifers and should be limited to the spring season. The storage period should not be more than a week or two; the shorter the time the better. The trees should be shaded, but a ventilated space of at least 1 foot above the trees should be provided if canvas or similar material is used.

In heel-in storage, a straight, broad V-shaped trench is dug to a depth of 8 to 12 inches, and the well-moistened soil is piled in a ridge at the back. Friable sandy to silt loam material is preferred. A thin layer of trees with not more than 1 inch of root-layer thickness is laid down, and a 2-inch layer of soil is immediately spaded out and placed on top of the roots. The soil

[14] Personal communication with E. J. George, Northern Great Plains Field Station, Agricultural Research Service, Mandan, N. Dak.

F-345374

FIGURE 39.—Heeling-in 1–0 ponderosa pine, Plumfield Nursery, Fremont, Nebr.

is firmed gently with the bottom of the foot (fig. 39). Successive layers of trees and soil are added until all the trees are heeled-in.

The soil must come well above the root collar, but it should not cover the needles. The layers should be of uniform depth. A light sprinkling may be done as heeling-in proceeds or shortly thereafter. Some nurserymen dip the roots of each bundle or handful of stock in water before heeling-in.

In shipment, larger quantities of planting stock usually are transported in 1½-ton trucks or larger units such as truck trailers. A 1½-ton truck can haul about 60,000 2–2, 90,000 3–0, or 180,000 2–0 trees if they are crated, and about 50 percent more of each class of stock if it is packed in bales. Pickup trucks are frequently used to transport smaller quantities of stock for shorter distances.

State nurseries usually rely on railway express shipments or motor freight for serving customers.

For the usual nonrefrigerated truck shipments, the chief precaution is a check for temporary load limits that may have been imposed along the route to be traveled during or following spring breakup. The cargo should be well protected against the sun and wind with tarpaulins. In warm weather, it may be possible to do most of the trucking at night. Watering enroute should not be necessary if loads of trees are properly packed and protected against wind and sun. When the destination is reached, the stock should be unloaded immediately in a building, under the shade of trees, or in a field icehouse constructed for stock storage.

POTTING AND BALLING NURSERY STOCK

Conifer nursery stock is potted or balled to increase field survival on nonirrigated lands in the drier portions of the Prairie-Plains. Potted stock is used in field-planting, whereas the more expensive balled stock is used most often in ornamental planting.

Ponderosa pine has rather poor root-producing ability (Stone 1955) and rather poor field survival when planted as bare-rooted stock in a zone from approximately the 101st meridian westward to the Rocky Mountain area. This zone includes areas in North Dakota with less than 16 inches of annual rainfall; areas in Nebraska with 19 inches or less; and areas in western Oklahoma and northwest Texas with 22 inches or less. This is a zone of high drought frequency (Bates 1935). In farm plantings under these conditions, consistently satisfactory conifer survival may be obtained only with potted stock. Potted trees are also used frequently to replace losses in plantings made originally with bare-rooted trees. The potting is usually done a full growing season before field-planting.

Potted stock has several advantages that favor high survival. Practically all the feeder roots are still intact when planted, whereas unpotted stock often loses some of these feeder roots when it is lifted. The root system of potted stock is more compact, has an optimum bond with the soil, and can continue uninterrupted extraction of moisture at the planting site; bare-rooted plants must re-establish this bond by extension of the root system. The reserve supply of moisture within the pot is adequate to enable the potted stock to withstand several weeks of drought, while the bare-rooted plant is immediately and totally dependent on whatever moisture it is able to extract from the planting site. The soil in the pot can be ideally proportioned to stimulate root development and can include substantial amounts of organic matter to increase the water-holding capacity. The roots or tops of potted stock are much less likely to heat or mold in transit than those of bare-rooted stock.

The principal disadvantage of potted trees is the higher unit cost. Some reasons for this increased cost are the materials and labor expended in the potting operation, the need for lathhouses or special structures to protect the potted trees during growth and storage, and the increased transportation costs for distribution to the planting site.

In western Oklahoma, potted eastern redcedar planted during 2 years of low precipitation had an average survival of 96 percent, compared to 70 percent for bare-rooted stock planted on the same site (Afanasiev et al. 1959). However, the following year both classes of stock had 94 percent survival.

In tests conducted by the Manhattan Nursery between 1949 and 1953, use of potted stock increased survival of juniper 15 to 20 percent and that of pine 30 to 40 percent.[15]

At the Northern Great Plains Field Station of ARS, initial survivals of 90 to 100 percent were obtained with potted ponderosa pine.[16]

In western Kansas, the pines and cedars are generally potted at the 2–0 age in April in 1½- by 2½- by 6-inch pots and held 1 year before shipment for shelterbelt planting. The 1–0 eastern redcedar sometimes is large enough to pot and hold for sale as 1–1.

Since bare-rooted Arizona cypress transplants poorly, potted stock is fieldplanted almost exclusively in the Southern Great Plains and the Southwest. It may be seeded under glass in November in flats of ground-up sphagnum moss, or in sterilized loamy sand soil. The seedlings are lifted in March when they are about 3 inches tall, and potted in asphaltic bands or in 2½-inch clay pots. Some of the potted seedlings are ready for fieldplanting the following spring; others are repotted in 1-gallon cans and left for another year.

Potted 16-month-old Arizona cypress ready for fieldplanting will be about 8 inches tall; 1–1 Austrian pine, 4 inches tall; 2–1 Austrian pine, 10 inches tall; 1–1 eastern redcedar, 10 inches tall; and 2–1 eastern redcedar, about 22 inches tall.

Asphaltic roofing paper is one of the materials used for pots. The method developed by Johnson (Johnson 1955, Johnson and Vanderslice 1956) illustrates its use. The 36-inch-wide rolls are cut lengthwise into three 1-foot-wide sections; then each section is cut into 12- by 12-inch sheets. The paper is given four creases to form a finished pot 2¾ by 2¾ by 10¾ inches and stapled at the edges five or six times. The bottom 1½ inches is creased.

A somewhat similar pot of 15-pound roofing felt was devised by Morris of the Soil Conservation Service and described by Downs (1954).

Manufacturers produce inexpensive, flat-packed, 15-pound asphalt-band pots with both ends open. Their sizes range from 2 by 2 by 6 inches to 3 by 3 by 6 inches. The 2½- by 2½- by 6-inch band contains enough soil for a 1- or 2-year-old pine or juniper seedling to grow an additional year and still feed through the standard fieldplanting machines. Such trees occasionally have been held a second year, but the pots tend to deteriorate and fall apart. A 30-pound paper has been better for trees carried in pots 2 years.

The use of growth promoters such as indoleacetic acid or vitamin B has resulted in root response on southern pines (Plank 1939). Fowells (1943), however, found no appreciable response in the number of secondary roots in ponderosa pine when similar treatments were applied just before the trees were placed in tar paper pots; however, the length of the root system was improved slightly.

Shaw (1963) describes a potting system developed by the Colorado State Forest Service. In this mechanized operation, a series of live conveyor belts is used to move the potting trays from step to step, and a soil packing machine is operated by hydraulic pressure. Other recently developed devices include a hexagonal soil pot equivalent to a standard 3-inch clay pot and a potting machine capable of forming 750 pots per man-hour; the range in the diameters of the pots is 1.6 to 3.2 inches (Food and Agriculture Organization 1954).

The 2½- by 2½- by 6-inch pots can be filled with soil, and about 750 to 1,000 plants per man-day can be set in. Tomato lugs (flats) that will hold 30 asphalt bands are used. A spacer is necessary to keep the pots open and lined up properly. They are tamped by jarring the whole flat. The bottom few inches of soil are tightly packed with a 2- by 2-inch tamper before the seedlings are placed in the pot and the pot is filled. The tamped plug keeps the soil from sliding out of the bottom of the pots while they are being transferred to a bed in a lathhouse. The pots when planted weigh about 2 pounds apiece.

Larger, heavy asphalt pots 6 inches in diameter and 7 inches deep can also be purchased on the open market, as can the 1-, 2-, or 4-gallon metal cans. The tapered 1-gallon metal pots have distinct advantages over vertical-walled 1-gallon fruit cans because the plant and its ball of soil can be more quickly and easily removed from them for planting; they are extensively used in commercial nurseries.

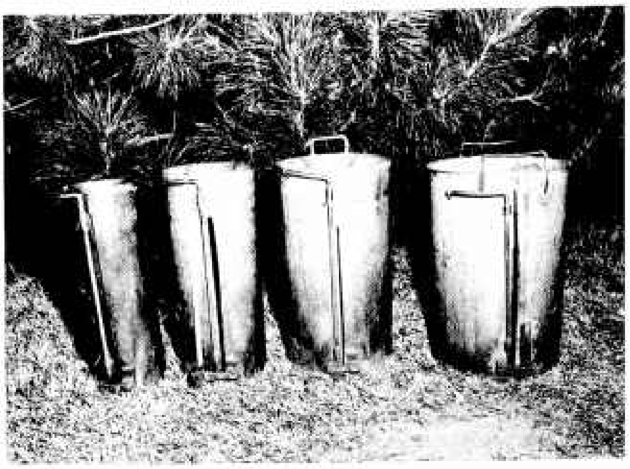
Tapered-steel cylinders have been used for a number of years at the Agricultural Research Station at Woodward, Okla.,[17] to lift trees for balling (fig. 40). The cylinders are 17½ inches long, are of 18-gage metal, and are about one-fourth to one-half inch smaller in diameter at the bottom than at the top. The following diameters are in use: 6, 8, 10, 16, 18, and 24 inches. When used, the cylinders are forced full depth into the soil around the trees. The tree and cylinder are then lifted. A clamp is released, the cylinder is lifted off the soil, and the ball of soil is wrapped in burlap.

The general idea of cylinder balling was adapted to a commercially manufactured, power-operated balling

[15] Personal communication with A. E. Ferber, Soil Conservation Service, Denver, Colo.

[16] Personal communication with E. J. George, Northern Great Plains Field Station, Agricultural Research Service, Mandan, N. Dak.

[17] Personal communication with E. W. Johnson, Southern Plains Field Station, Agricultural Research Service, Woodward, Okla.



F–488079

FIGURE 40.—Transplanting cylinders with 6-, 8-, 10-, and 16-inch top diameters used to expedite balling of conifers in sandy soils, Woodward, Okla.

machine. It functions well if soils are medium-textured, free of stones, and have a good soil moisture content, and if many trees of uniform size can be dug without frequent change of cylinder size. Balling and burlapping has been a standard method for handling larger ornamental stock in the commercial nursery industry for many years (fig. 41).

In recent years, heavy paper, plastic, metal, or other types of containers, about 8 to 20 inches in diameter, have found favor in the handling and shipping of evergreens in the 2- to 5-foot height class.

The potting mixture used in Prairie-Plains commercial nurseries in the 1-gallon or larger containers is generally about two parts of fertile topsoil, one part peat moss, and one part sand. In some nurseries one-fifth pound of high-analysis commercial fertilizer, such as ammonium phosphate, per cubic yard, is added. In other nurseries 1 pound of Milorganite per wheelbarrow of mix is used. In potting Arizona cypress and pines with top soil that has some alkalinity (pH 7.5 to 7.7), some Southern Plains nurserymen use several pounds of "sulfa soil" per cubic yard to reduce the pH and make phosphates and iron more available. All material is run through a shredder.

In areas where good topsoil is becoming increasingly more expensive, some nurseries use a 75–25 mixture of moderately acid fine sand and peat; each cubic yard is fortified with 6 ounces of potassium nitrate, 4 ounces of potassium sulphate, 2½ pounds of ordinary superphosphate, 4½ pounds of dolomitic limestone, 1¼ pounds of calcium carbonate lime, and 1¼ pounds of gypsum (Matkin and Chandler 1957, Baker et al. 1957). In a supplemental treatment, liquid feeding with nitrogen fertilizers is used; 1 pound of 33 percent ammonium nitrate per 100 gallons of water (Matkin and Chandler 1957) or a complete N-P-K (nitrogen, phosphorus, potash) fertilizer is applied.

Details have been published on potting-soil mixtures and their basic ingredients, fortification with dry fertilizers, use of additional liquid fertilizers, disease control, and efficient mechanization of all aspects of the growing of plants in containers (Baker et al. 1957).

F–475115

FIGURE 41.—Balling and burlapping blue spruce, Esmond, N. Dak.

AGE CLASSES OF STOCK NEEDED FOR THE PLAINS

Both transplants and seedlings are produced for planting in the Plains. In the North transplants are used almost exclusively, while in the South seedlings as well as transplants are used. Good-quality stock is required. Such stock has a large amount of fibrous root system and a top about 6 to 12 inches from the ground line to the tip of the terminal bud (or tip of cedars) (fig. 42). It should have a thick, sturdy stem that will hold the plant erect despite wind, clods thrown against it in cultivation, or the matting-down action of snow, weeds, or grass.

The age class to which a tree species should be grown to attain a proper root system, stem caliper, and height largely depends on the length of the growing season and the tree species. The level of soil fertility is another important factor.

The usual age classes of stock by species used in field-planting and nursery transplanting under Prairie-Plains conditions are given in table 13. Species selection is largely dictated by past performance in survival, growth, ease of establishment, and relative freedom from serious pests. State extension foresters, research

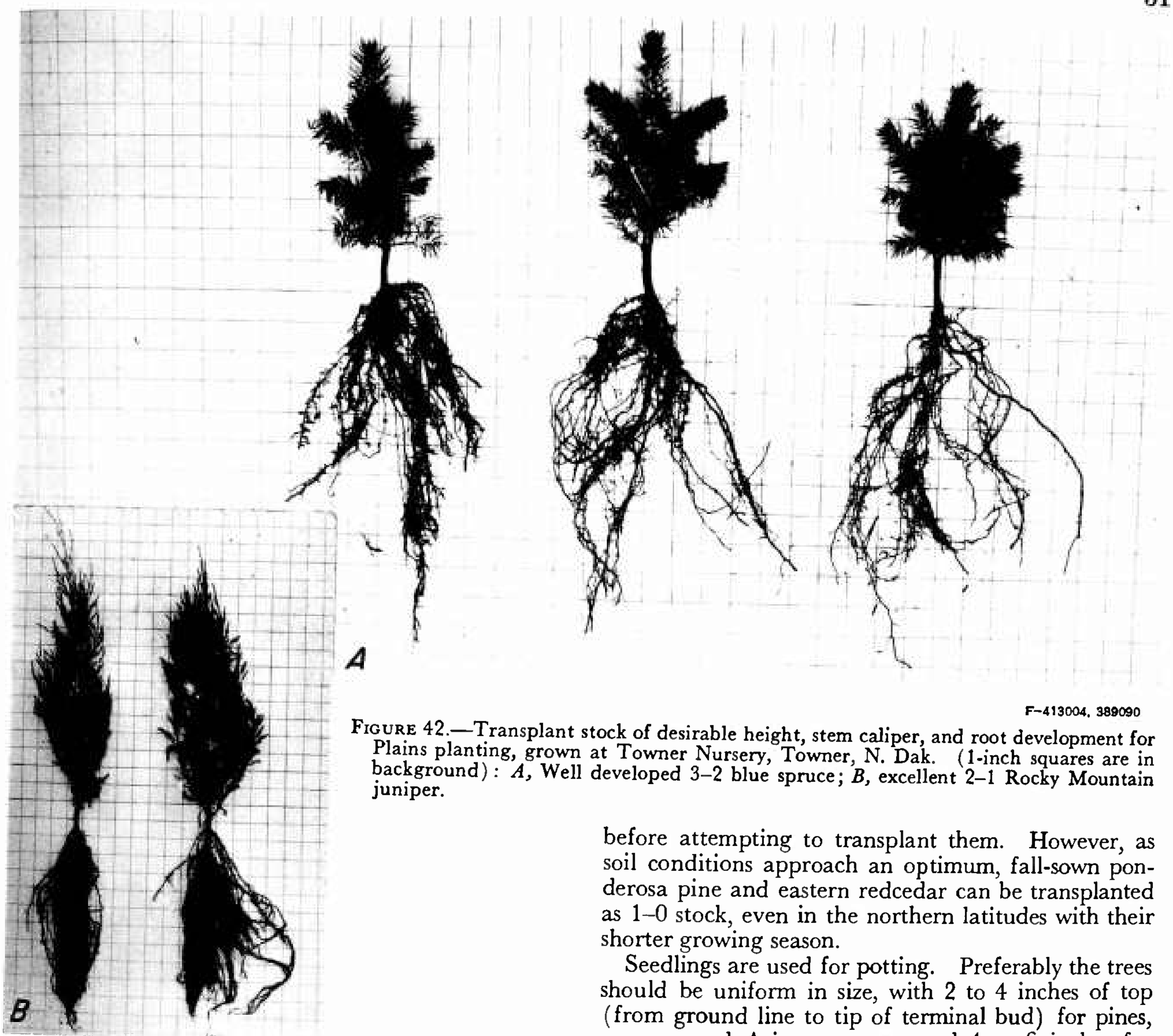


FIGURE 42.—Transplant stock of desirable height, stem caliper, and root development for Plains planting, grown at Towner Nursery, Towner, N. Dak. (1-inch squares are in background): *A,* Well developed 3–2 blue spruce; *B,* excellent 2–1 Rocky Mountain juniper.

foresters, horticulturists, and others have prepared numerous guides and observations on tree species adaptable to the Plains. Current summaries include those of George (1953, 1957) and Read (1958).

Stock suitable for transplanting in the nursery is 1 to 3 years of age. In the Dakotas, spruces and firs are grown to a 2–0 or 3–0 age; junipers, redcedars, jack pine, and Scotch pine to a 2–0 age; and ponderosa pine to a 2–0 or occasionally 1–0 age before transplanting. From Nebraska south to Texas, eastern redcedar is usually transplanted as 1–0 stock, and Rocky Mountain juniper as 1–0 or 2–0. Ponderosa pine is transplanted as 2–0 or 1–0; the former age is more prevalent in Nebraska.

The influence of increasing age class and the benefits of transplanting are illustrated in figure 43.

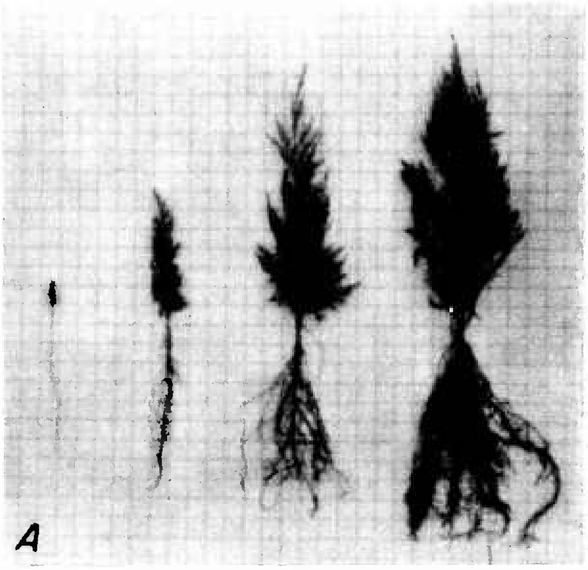
In northern nurseries it is generally better to grow the conifers, including ponderosa pine, to the 2–0 age before attempting to transplant them. However, as soil conditions approach an optimum, fall-sown ponderosa pine and eastern redcedar can be transplanted as 1–0 stock, even in the northern latitudes with their shorter growing season.

Seedlings are used for potting. Preferably the trees should be uniform in size, with 2 to 4 inches of top (from ground line to tip of terminal bud) for pines, spruces, and Arizona cypress and 4 to 6 inches for junipers. This size is generally attained in 2 or 3 years by spruces, in 2 years by pines, in 1 year by juniper in the Southern Plains and in 2 years in the Central or Northern Plains, and in 3 months by Arizona cypress.

The dimensions of typical species and of a number of age classes vary among nurseries in the Northern, Central, and Southern Great Plains (tables 14 to 16). Generally the size of comparable age classes of the same species increases from north to south.

Well-balanced trees have a rather high proportion of their total weight in roots. Such plants have a better chance of survival under the high transpiration stress of difficult dry planting sites. The top-root ratio of good transplants generally ranges from 2.0 : 1 to 3.5 : 1.

In contrast, 2–0 or 3–0 seedlings of somewhat comparable top length have a top-root ratio of 4.0 : 1 to 6.0 : 1. Moreover, in the seedling stock, a higher proportion of the weight of top is in the needles (a reflection of the size of the transpiration mechanism).



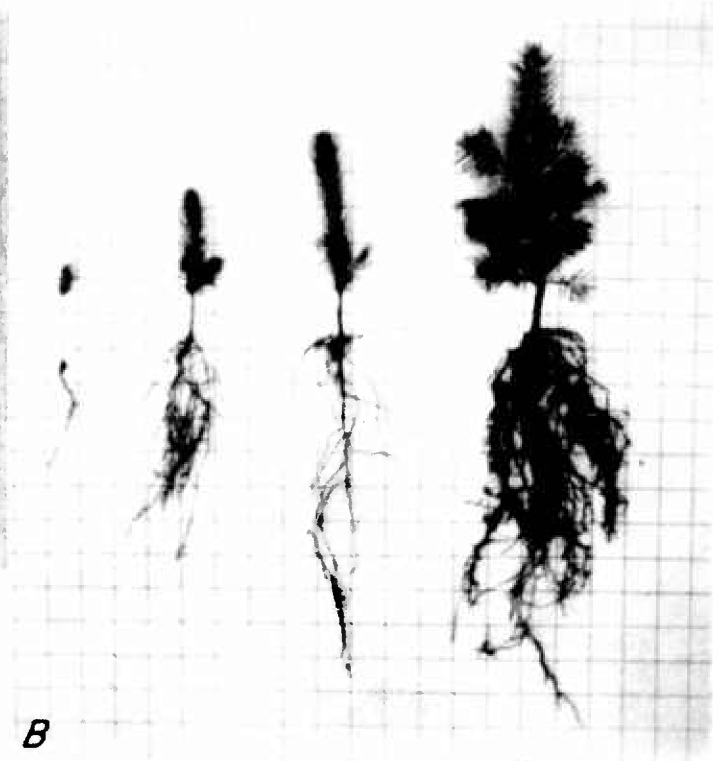


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FIGURE 43.—Size and root development of nursery conifers as affected by age class and species, Towner Nursery, Towner, N. Dak. (1-inch squares are in background): *A,* Rocky Mountain juniper, from left to right, 1–0, 2–0, 3–0, and 3–1; *B,* blue spruce, from left to right, 1–0, 2–0, 3–0, and 3–2; *C,* Scotch pine, from left to right, 1–0, 2–0, 3–0, and 3–2.

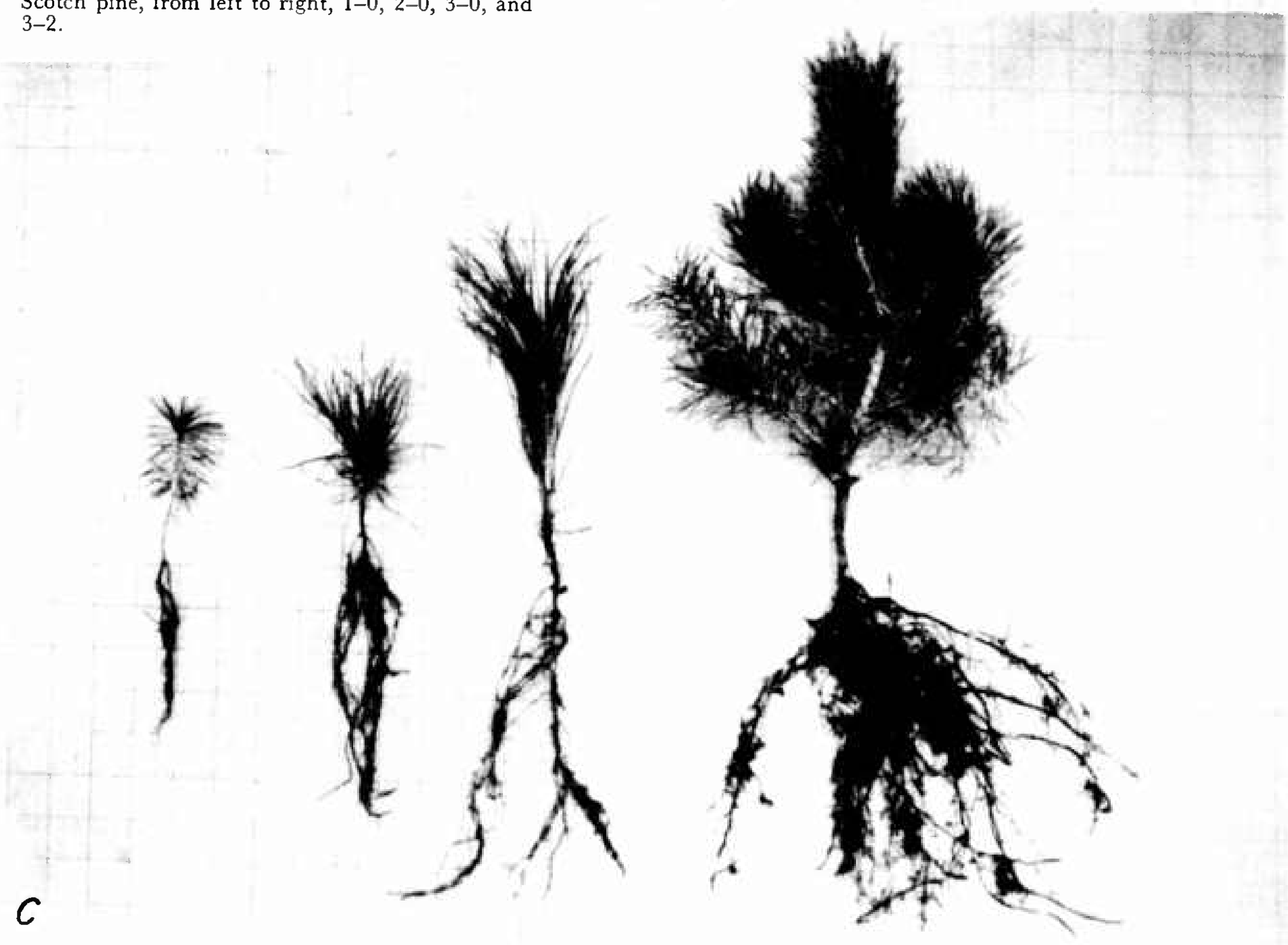

TABLE 13.—*Age classes and species of conifers commonly used and being tested in the Prairie-Plains of the Midwestern United States and nearby Canada*

Species [1]	Age class	Areas where grown
Arborvitae, Oriental	1–0	Okla., Tex.
	2–0	Do.
Cypress, Arizona	1–0	Okla.,[2] Tex.
Douglas-fir [2]	2–2	Canadian Plains, N. Dak., S. Dak.
Fir:		
Balsam [2]	2–2	Canadian Plains
Siberian [2]	2–2	Do.
Juniper:		
Common [2]	2–1	N. Dak., S. Dak., Nebr.
Ashe	2–0	Okla.,[2] Tex.
	1–1	Okla., Tex.
One-seed	2–0	Kans.,[2] Okla.,[2] Tex.
	1–1	Kans., Okla., Tex.[2]
Rocky Mountain	2–0	Canadian Plains, Okla., Tex.
	1–1	Okla., Tex.
	2–1	Canadian Plains,[2] N. Dak., S. Dak.
	1–2	Kans., Nebr.
	2–2	N. Dak., S. Dak.
Larch:		
European	2–1	Canadian Plains
	2–2	Do.[2]
Siberian	2–1	Canadian Plains, N. Dak.
	2–2	Canadian Plains,[2] N. Dak.[2]
Pine:		
Austrian	2–0	Okla., Tex.
	1–1	Okla.,[2] Tex.[2]
	2–1	S. Dak., Nebr., Kans.
	2–2	S. Dak., Nebr.
Digger [2]	1–0	Okla.
	1–1	Do.
Italian stone [2]	2–0	Do.
	1–1	Do.
Jack	1–1	Nebr.
	2–1	Canadian Plains, N. Dak., S. Dak., Nebr.
Pine—Continued		
Japanese black	2–0	Okla.
	1–1	Do.[2]
Japanese red	2–0	Do.
	1–1	Do.[2]
Limber [2]	2–1	Okla., Tex.
	2–2	N. Dak., S. Dak., Nebr., Kans.
Loblolly [2]	1–0	Okla.
Lodgepole	2–1	Canadian Plains [2]
	2–2	Do.
Pinyon [2]	2–0	Kans., Okla., Tex.
	1–1	Do.
Ponderosa	2–0	Okla., Tex.
	1–1	Do.
Ponderosa	1–2	N. Dak., S. Dak., Nebr., Kans.
	2–2	Canadian Plains, N. Dak., S. Dak.
Scotch	2–1	Do.
	1–2	S. Dak., Nebr., Kans.
	2–2	Canadian Plains, N. Dak.
Shortleaf	1–0	Okla., Tex.
Swiss stone [2]	2–2	Canadian Plains, N. Dak., S. Dak.
Redcedar, Eastern	2–0	N. Dak., Nebr., Okla., Tex.
	1–1	Nebr., Kans., Okla., Tex.
	1–2	Nebr., Kans.
	2–1	N. Dak., S. Dak.
	2–2	S. Dak.
Spruce:		
Blue	2–2	Canadian Plains, N. Dak., S. Dak., Nebr., Kans.[2]
	2–3	Canadian Plains, N. Dak.
	3–2	Do.
Siberian [2]	2–2	Do.
White	2–2	Canadian Plains, N. Dak., S. Dak., Nebr.
Tamarack [2]	2–1	N. Dak.

[1] See Appendix for scientific names.
[2] Not used extensively, still being tested, or receiving restricted use in areas of better rainfall.

TABLE 14.—*Measurements of various age classes of Towner Nursery stock, Towner, N. Dak., fall 1941 and spring 1958*

Age class	Species	Trees per square foot		Trees measured	Length		Stem diameter	Fresh weight per plant	Top-root ratio based on green weight
		Seedbed	Transplant bed		Top	Root			
		Number	*Number*	*Number*	*Inches*	*Inches*	*64ths inch*	*Grams*	
1–0	Eastern redcedar	30		15	2.9	7.2	3	1	2.6
2–0	.....do	40		10	6.8	8.2	9	13	2.8
1–1	.....do	40	16	10	5.4	9.8	8	10	1.8
1–0	Rocky Mountain juniper	20		10	2.9	6.5	3	1	2.3
2–0	.....do	30		15	5.2	8.9	5	3	2.0

TABLE 14.—*Measurements of various age classes of Towner Nursery stock, Towner, N. Dak., fall 1941 and spring 1958*—(Continued)

Age class	Species	Trees per square foot		Trees measured	Length		Stem diameter	Fresh weight per plant	Top-root ratio based on green weight
		Seedbed	Transplant bed		Top	Root			
		Number	*Number*	*Number*	*Inches*	*Inches*	*64ths in.*	*Grams*	
[1] 3–0	Rocky Mountain juniper (Cont.)	5	....	10	15.9	11.6	25	87	4.2
2–1	.....do.....................	30	16	10	7.5	8.3	7	7	2.0
[2] 2–2	.....do.....................	50	16	15	14.0	10.6	14	38	3.3
[3] 2–2	.....do.....................	50	16	10	11.3	10.4	13	31	3.7
[4] 2–2	.....do.....................	50	16	10	6.0	10.9	14	25	2.1
1–0	Ponderosa pine..............	40	....	15	1.6	7.6	4	1	1.4
2–0	.....do.....................	....	....	20	2.7	8.5	6	3	1.5
[2] 3–0	.....do.....................	26	....	10	6.2	8.6	15	20	6.1
[5] 3–0	.....do.....................	13	....	14	4.4	9.7	14	16	4.7
1–1	.....do.....................	40	16	10	3.1	8.3	10	9	2.2
2–1	.....do.....................	(6)	(6)	20	4.6	13.3	15	23	3.7
2–2	.....do.....................	40	16	15	7.6	14.0	21	58	3.4
1–0	Scotch pine.................	30	....	10	1.6	4.2	2	(7)	1.1
2–0	.....do.....................	30	....	10	2.4	7.8	8	4	2.5
[8] 3–0	.....do.....................	30	....	15	5.0	8.8	9	5	3.6
[9] 3–0	.....do.....................	30	....	15	2.5	7.5	6	3	3.2
2–2	.....do.....................	40	16	15	7.8	11.2	17	32	2.6
1–0	Blue spruce.................	18	....	10	0.7	5.5	2	(7)	1.3
2–0	.....do.....................	(6)	....	20	2.7	7.9	4	2	2.2
3–0	.....do.....................	73	....	15	4.9	8.2	7	4	2.3
2–1	.....do.....................	(6)	....	20	4.4	11.4	10	5	1.2
2–2	.....do.....................	(6)	....	20	6.8	18.2	17	26	1.9
3–2	.....do.....................	75	16	15	6.3	9.2	13	22	2.3
2–0	Jack pine...................	20	....	15	3.6	9.5	8	7	3.2

[1] Low seedbed density. [2] Not top pruned. [3] Top pruned at 8 inches. [4] Top pruned at 4 inches. [5] Top pruned at 4 to 5 inches [6] Data not available. [7] Less than 1 gram. [8] Mycorrhizal soil. [9] Nonmycorrhizal soil.

TABLE 15.—*Measurements of various age classes of Bessey Nursery stock, Halsey, Nebr., spring 1958*

Age class	Species	Trees per square foot		Length [1]		Stem diameter [1]	Fresh weight per plant [1]	Top-root ratio based on green weight
		Seedbed	Transplant bed	Top	Root			
		Number	*Number*	*Inches*	*Inches*	*64ths inch*	*Grams*	
2–0	Eastern redcedar....................	50	....	9.2	14.9	16	38	2.5
1–1	.....do...........................	(2)	17	5.6	11.7	7	9	1.5
1–2	.....do...........................	(2)	17	12.6	18.9	14	26	2.1
1–0	Rocky Mountain juniper............	60	....	2.3	5.5	2	1	2.3
1–2	.....do...........................	(2)	17	8.0	13.6	13	18	2.5
1–0	Ponderosa pine.....................	50	....	1.4	6.6	4	2	1.7
2–0	.....do...........................	50	....	4.0	12.0	14	17	1.6
1–1	.....do...........................	(2)	17	3.3	12.5	12	8	2.0
1–2	.....do...........................	(2)	17	5.5	15.6	18	27	3.0
2–1	.....do...........................	(2)	17	2.9	11.0	12	8	1.6
2–2	.....do...........................	(2)	17	13.4	22.0	32	109	4.1
1–0	Austrian pine......................	50	....	1.2	7.3	3	1	1.7
2–0	.....do...........................	50	....	2.7	11.0	6	4	1.6
2–1	.....do...........................	(2)	17	4.3	14.2	12	15	1.5
2–2	.....do...........................	(2)	17	12.2	26.2	21	75	2.8
2–0	Red pine...........................	60	....	1.4	11.6	7	6	.6
2–1	.....do...........................	(2)	17	4.4	12.5	12	12	1.2
1–0	White spruce.......................	75	....	.5	2.6	1	(3)	2.0
1–0	Blue spruce........................	75	....	.7	3.6	1	(3)	.5
2–1	.....do...........................	(2)	17	3.1	10.1	6	5	.8
2–1–1	.....do...........................	(2)	17	4.5	9.5	7	9	1.2

[1] Twenty trees were measured for each combination of species and age class except blue spruce 2–1–1, for which only 16 trees were measured.

[2] Data not available.

[3] Weights less than 1 gram.

TABLE 16.—*Measurements of various age classes of Norman Nursery stock, Norman, Okla., spring 1958*

Age class	Species	Trees per square foot of seedbed	Length [1]		Stem diameter [1]	Fresh weight per plant [1]	Top-root ratio based on green weight
			Top	Root			
		Number	*Inches*	*Inches*	*64ths inch*	*Grams*	
1–0	Eastern redcedar	40	5.4	10.3	6	5	3.6
2–0	.....do	40	17.0	15.8	19	48	3.6
1–0	Ponderosa pine	30	2.4	8.9	6	2	2.3
2–0	.....do	30	6.6	13.0	16	21	3.4
3–0	.....do	30	12.2	17.0	24	47	4.2
1–0	Austrian pine	35	1.9	7.6	3	2	3.4
2–0	.....do	35	5.3	12.2	12	14	2.8
3–0	.....do	35	10.9	22.3	22	52	3.4
2–0	Swiss stone pine	50	16.9	11.1	16	38	5.4
3–0	.....do	50	18.3	18.2	21	55	3.5
2–0	Digger pine	10	14.9	17.8	23	57	2.9
2–0	.....do	10	15.2	17.9	23	58	3.0

[1] Twenty trees were measured for each combination of species and age class except digger pine, for which 40 trees were measured.

INVENTORY

Each nurseryman must know the number of trees, by species and age class, in his nursery so nursery and fieldplanting activities can be properly coordinated and costs of production can be determined. As it is normally impractical to make 100-percent counts, adequate sampling must be employed. Because of the more rigorous climate, stands of conifers in Plains nurseries are generally not as uniform as those elsewhere in the country; thus, a larger sample is required to secure estimates within the required accuracy limits. Methods needed to obtain the counts are the same as those necessary in the South (Wakeley 1954) or the Lake States (Stoeckeler and Jones 1957).

An inventory which considers the causes of variation in the average stand per square foot of producing area should be made for each seeding. These variables may include seed source, age of stock, species, year of seed collection, season of sowing or transplanting, and other factors. The cost of this inventory should be only a few cents per thousand seedlings if the percentage of sample is properly gaged to the overall totals of the classes listed above.

For the seedling inventory, it is common practice to make two estimates—one of the total living seedlings in a nursery block, or unit of it, and another of the percentage of these seedlings that are plantable. The accuracy of the final estimate of tree numbers will be increased if (1) the random or systematic location of sampling points provides a good cross section of conditions on the entire area; (2) the counts are made accurately; (3) the grading specifications used to determine the percentage of seedlings in the sample that are plantable are the same as will be used at the time of lifting and shipping; and (4) the person making the inventory is not biased.

A 4.0- by 0.5-foot strip across the seedbed is a common sampling unit of inventory in the Lake States (Stoeckeler and Jones 1957); a 4- by 1-foot strip is usually used in Southern nurseries (Wakeley 1954). More samples can be obtained from the smaller strip in the same time, and they will yield more accurate estimates of the total, especially where the beds are nonuniform.

The area is defined by a frame of wood, steel welding rods, or flat steel strips reinforced with one or more crossbars. The frame may be open at one end for ease of placement on the bed, but it should be rigid enough to have a constant inside dimension of the sample size desired.

The number of 4.0- by 0.5-foot sample counts that can be taken per 8-hour day where seedlings average about 45 to 50 per square foot is as follows (Stoeckeler and Jones 1957):

Class of stock	*Sample counts (number)*
1–0	120–160
2–0	90–120
3–0	80–100

The intensity of the sample taken will be determined by the accuracy of the count required, the purpose of the inventory, and the area and uniformity of stocking of the seedbeds and transplant beds. More samples are required for nonuniform beds or for areas of seedbeds that are less than 10,000 square feet, assuming that the same degree of accuracy is needed.

A 1½-percent estimate or three counts per hundred lineal feet of seedbed has been sufficient for areas larger than 10,000 square feet (2,500 lineal feet) that have a uniform density. Estimates within 5 percent of the correct total will be obtained in two of three trials. Many nurserymen use 10 sample counts per 500-foot bed.

The location of the samples within the beds may be random or systematic, but it should be determined prior to sampling. In a systematic layout, samples are placed at regular intervals in the bed, the distance between samples depending on the total number to be taken. The sampling points are located by pacing or measuring. Counts can be made most advantageously by a two-man crew, one man working on each side of the bed and counting approximately half of the bed. To avoid duplication or misses, smaller units of the area on which the trees are counted can be marked on the ground or indicated on the sampling frame.

A prepared form is used to record the counts. The example shown below has 20 to 25 lines per sheet (Wakeley 1954).

______________________ Nursery Inventory

(Name)

Compartment Number..........	Length of bed..........
Date of Inventory..........	Species..........
Recorder..........	Seed source..........
Measurement started..........	Date sown..........
N E S W end of bed (Circle one)	Cultural treatment..........
	Uniformity of stocking..........

Bed number	Distance along bed	Living seedlings	Plantable seedlings	Bed number	Distance along bed	Living seedlings	Plantable seedlings
	(Feet)	(Number)	(Number)		(Feet)	(Number)	(Number)

Each sample is shown separately; the trees in each lot are calculated.

The estimate of the number of plantable seedlings is obtained by digging and counting the plantable seedlings in a subsample of the plots used previously to determine the total number in a unit of the nursery. These subsamples are selected mechanically at the time the total inventory is made—for example, by marking every fourth plot for digging. About 30 subsamples per unit should be dug. Plot the percent plantable on cross-section paper over the average number of seedlings per square foot on each subsample. A straight line drawn through these points gives an estimate of percent plantable over density for a particular unit of the nursery. The average density of seedlings per square foot in the nursery unit is then determined, and the percent plantable for this density is read from the graph. This percentage is then applied to the estimated total number of seedlings in the nursery unit to obtain an estimate of the number plantable. Allowance must be made for seedling growth from the time of inventory to time of shipment and for mechanical injury during lifting. The accuracy in making corrections can be improved by careful observation and study, and the nurseryman should attempt to develop a set of correction factors for his own nursery.

Because of greater uniformity in transplant beds, less intensive sampling is required for the same accuracy. The sampling unit for machine-transplanted trees is generally a 6-foot-long section of an individual row. When transplanting is done across the bed with 4- to 6-foot-long transplant boards, the sampling unit is the individual row corresponding to the bed width. In counting transplants a 6-foot-long wooden pole (or one corresponding to the bed width) with a long, thin nail or heavy, 4-inch-long wire bent at right angles to the pole at each end will serve as a sampler.

Where there are about 30 transplants per 6 feet of row, 160 to 200 samples are counted per 8-hour man-day. The percentage of plantable trees in transplant age classes can be estimated very closely on the basis of stem caliper and height, so no digging of samples is required.

SOIL MANAGEMENT

The problems in selecting a nursery site in the Plains with the best combination of physical and chemical soil characteristics for conifer production have already been emphasized. Furthermore, since both tops and roots of the trees grown in the nursery are removed from the soil, continued high-level production of quality stock requires systematic replacement of the nutrients.

This section presents soil management practices designed to develop the nursery soil into its highest productive state and to maintain it in that condition. Major subjects discussed are fertility requirements for conifer production, determination of nutrient needs by soil testing and visual observation of symptoms of malnutrition, application of chemical and organic fertilizing materials, maintenance of soil acidity at favorable levels for conifers (pH may change as a result of irrigation), and the great importance of soil inhabiting organisms such as mycorrhizal fungi to seedling development and their introduction into nursery soils.

Many experiments, replicated 4 to 10 times, were installed in four nurseries and more than 1,000 beds in the Dakotas to test soil fertility and pH adjustment. Randomized blocks, Latin squares, and similar statistical designs were used. In the following discussion details from a few of these experiments are presented to illustrate certain effects.

FERTILITY REQUIREMENTS AND THE DETERMINATION OF NUTRIENT NEEDS

A proper level of soil fertility and physical condition is a prime essential to good nursery management. The fertility level is important not only in producing adequate growth but also in imparting frost hardiness (Kopitke 1941) and drought hardiness (Shirley and Meuli 1939).

Based on the analysis of the surface 6 to 8 inches of soil of a number of nursery beds in the Northern Plains where good seedling growth was observed, adequate levels of fertility were determined to be as follows (Stoeckeler and Arneman 1960):

Total nitrogen (percent)	0.13
Available nitrogen (pounds per acre of ammonia and nitrate nitrogen)	40.0
Organic matter (percent)	2.5
Available phosphorus (pounds per acre of P_2O_5)	150
Available potash (pounds per acre of K_2O)	250
Cation exchange capacity (milliequivalents per 100 grams)	12.0
Replaceable calcium (milliequivalents per 100 grams)	10.5
Replaceable magnesium (milliequivalents per 100 grams)	2.4
Total replaceable bases (milliequivalents per 100 grams)	14.2
pH (for juniper species)	6.5–7.5
pH (for ponderosa and Austrian pine)	6.0–7.0
pH (for spruces, Scotch pine, and jack pine)	5.5–6.3

Testing procedures are those compiled by Wilde and Voigt (1955).

Soils of the Plains usually have large calcium, magnesium, and potassium contents. Soils with the recommended texture selected for conifer nursery purposes are likely to be deficient in phosphorus and occasionally in nitrogen. Some sulfur deficiency is reported for general farm crops in eastern Nebraska (Jordan and Reisenauer 1957), and some boron response has been noted in eastern Nebraska, Kansas, Oklahoma, and western Texas (Russel 1957). Norum et al. (1957) report for the Northern Plains a general phosphate response, some nitrogen response, and an iron deficiency in calcareous soils.

The best quick method to determine any shortage in nutrients is to take 6 to 12 samples from the surface 8 inches of soil of the nursery, keeping the samples separate by past cropping and soil treatment history, soil texture, and topographic variations, and referenced to a map of soil type. The soil samples, properly labeled, can be tested at the agronomy and soils department of the agricultural colleges, generally on a standard cost basis. Directions in labeling, packaging, shipping, and payment will be supplied by these departments or county agents. In the test, at least the following five items must be determined: Total nitrogen, available phosphorus, available potassium, pH, and silt-plus-clay content.

The tests for total nitrogen, available phosphorus, and available potassium, when compared with the fertility table, will usually reveal any serious deficiency. Because of different extraction methods, soil testing techniques are likely to indicate different quantities (in pounds per acre) of available phosphorus and available potassium. Consequently, it is sufficient that the contents of both of these nutrients rank as high or very high, regardless of the method used. Fertilizer should be applied to remedy shortages. Fertilizer test plots can be used to verify the need and degree of response.

The tests for pH should be electrometric; they will reveal actual or potential alkalinity problems and the amount of acidification, if any, that is needed. The silt-plus-clay content provides a good general guide, especially on the first soil tests run on the site, as to its probable water-retaining ability and cation-exchange capacity. The areas with the lowest silt-plus-clay content are most likely to be low in water-holding capacity, organic matter, and nutrients generally. These deficient spots may need more manure, peat, compost, and commercial fertilizers than do the areas of higher silt-plus-clay content. Differential treatment of the nursery areas based on soil analysis will result in maximum overall benefits from the fertilization.

VISUAL SYMPTOMS OF MALNUTRITION

Soil tests help provide estimates of the probability of specific nutrient deficiency, but the nurseryman should also use other aids. One is a small-scale test of fertilizer response. A second aid is observation of visual symptoms of malnutrition such as the vigor and evenness of growth, foliage color, and the length and vigor of needles and buds.

The chief visual symptoms of malnutrition in Prairie-Plains conifer nurseries are likely to be (1) a yellow chlorotic condition due to immobility of iron in the plant, probably induced by excess lime carbonate; (2) a purplish color in spring and midsummer on spruces and some pines due to phosphate deficiency; and (3) a patchy, uneven appearance of beds (especially in newly established nurseries) due to lack of uniform mycorrhizal inoculation, invariably accentuated by phosphate starvation.

When such symptoms of malnutrition are visible, the trees can sometimes be saved by the treatments described in table 17. In cases of advanced malnutrition, the treatment may not result in any spectacular cure, and salvaging may have to be limited to usable stock, or the beds may have to be written off as a total loss.

In alkaline soils, iron may be immobile. As a remedy, enough acidifying material is added to the soil to make it moderately acid. This action stimulates a process known as chelating, which results in mobility of the iron. The effect of organic matter aids chelating. Special iron chelates, superior to iron sulfate, have been used in some horticultural crops to correct the problem, but they have not received much use in Prairie-Plains nurseries.

TABLE 17.—*Symptoms of malnutrition in Prairie-Plains coniferous nursery stock*

Deficiency or excess	Age classes and species observed	Symptoms and other detection methods	Treatment required per acre
Mycorrhizae deficiency.	2–0 and 3–0 in jack, Scotch, and ponderosa pine, and blue and white spruce.	The beds are patchy and uneven. Mycorrhizal fungi are absent except on trees in patches of good development.	Work mycorrhizal soil, leaf mold, or compost into soil, preferably between drills, and acidify with one-half to 1 ounce of iron sulfate or aluminum sulfate applied in solution per square foot. If tests show available phosphate to be low, apply 600 lbs. of 20-percent superphosphate or its equivalent per acre.
Phosphate deficiency.	1–0, 2–0, and 3–0 in white and blue spruce.	1–0 and 2–0 stock has a purplish needle color in late spring and midsummer; it is sometimes yellowish in 3–0 stock. Needles are short and may turn brown, terminal buds are poorly developed, and lateral buds are weak or absent. Soil tests may show low available phosphorus content.	Apply 600 to 1,000 pounds of 20-percent superphosphate per acre or 680 pounds per acre of 11–48–0 ammonium phosphate.
Iron deficiency......	1–0 and 2–0 in ponderosa and jack pine.	Trees tend to have pale yellow-green needles. Soil may be alkaline in reaction.	Use iron chelates or apply iron sulfate as a foliage spray in a 1-percent solution, wetting needles thoroughly. If not cured, repeat treatments using up to one-fourth avd. ounce per square foot of iron sulfate.
Excess alkalinity.....	All age classes of ponderosa, Scotch, and jack pine.	Trees have stunted buds and yellow or greenish-yellow needles. Soils may be in a pH range of 7.7 to 8.8.	Rake 1½ avd. ounces of aluminum sulphate per square foot between drills or rows and water heavily.

The worst deficiency problems are often interrelated. Problems such as excessive alkalinity may result in iron and phosphate starvation and probably manganese starvation, and also in spotty distribution of mycorrhizal fungi. Often a drastic lowering of pH results in a chain-reaction benefit that increases the availability of three or four nutrient elements, furthers growth of mycorrhizal fungi, and suppresses certain damping-off and root rot organisms.

Some colors, such as purple, bronze-purple, or violet, may be misinterpreted. Purpling is the normal fall color change of some species, especially 1–0 seedlings of some pine species and eastern redcedar. (See section on hardening-off). The degree of color change is less in the second-year or older pine stock, but it occurs in older age classes of eastern redcedar. The purpling due to fall color change persists until late spring, when it disappears. The purpling due to phosphate deficiency is apparent throughout the growing season.

FERTILIZER APPLICATIONS AND THEIR RESULTS

To obtain the maximum benefit from fertilizing materials, nursery soils should be at the optimum pH level for the species being produced and should be well supplied with organic matter and mycorrhizal fungi. The lack of one or more of these requirements may reduce the effect of fertilization.

A study of response by Rocky Mountain juniper to a number of organic and chemical fertilizer combinations, with and without acidification, was made at the Towner Nursery in North Dakota; each treatment was replicated 10 times on 4-foot-square subplots (table 18). The nursery soil was a Sioux loamy sand. Size was not increased because of acidification (treatment 2), but there was a strong response in size due to complete commercial fertilizer (treatment 8), to manure (treatment 7), to commercial fertilizer plus peat (treatment 9), and to commercial fertilizer plus manure (treatment 10). Of the three major fertilizers, nitrogen gave the most response (treatment 3), phosphorus some (treatment 4), and potash none (treatment 5). Only peat gave no response (treatment 6).

Colorado blue spruce reacted quite differently (table 19). Fertilizer alone gave no appreciable response. The acid treatment alone or in combination with mycorrhizal soil or Nitrophoska gave the most effect, doubling the weight of plants but, probably because of acid injury, lowering the number of trees slightly. Other spruces, and most pines, tended to respond somewhat similarly to the Colorado blue spruce to acidification and fertilizers. Each treatment was replicated five times in a Latin square, with 4-foot-square subplots.

TABLE 18.—*Effect of fertilization and acidification on 2–0* Juniperus scopulorum *at Towner Nursery, Towner, N. Dak.*

Treatment no.	Treatments per unit of area [1]	2–0 trees per square foot	Length: Top	Length: Root	Stem diameter	Total green weight per plant	Top-root ratio based on weight
		Number	*Inches*	*Inches*	*64ths inch*	*Grams*	
1	None	3.8	5.6	9.1	8	7.44	2.7
2	Aluminum sulfate, 1 ounce per square foot	3.6	5.6	8.7	7	8.21	2.7
3	Ammonium sulfate, 400 pounds per acre	4.0	6.2	9.8	7	9.43	2.8
4	Superphosphate, 800 pounds per acre	3.7	5.9	9.5	9	8.93	2.6
5	Potash, 200 pounds per acre	4.0	5.4	9.2	8	6.95	2.8
6	Towner peat, 20 tons per acre	4.3	5.4	9.1	8	6.95	2.7
7	Sheep manure, 20 tons per acre	3.5	6.5	9.5	9	10.42	2.8
8	Ammonium sulfate, 400 pounds; superphosphate, 800 pounds; potash, 200 pounds per acre	4.5	5.6	9.2	8	9.20	2.7
9	Ammonium sulfate, 400 pounds; superphosphate, 800 pounds; potash, 200 pounds; Towner peat, 20 tons per acre; aluminum sulfate, 1 ounce per square foot	4.3	6.4	9.6	9	10.09	2.9
10	Nitrophoska, 100 pounds; sheep manure, 20 tons per acre; aluminum sulfate, 1 ounce per square foot	3.5	7.5	9.7	10	13.36	3.2

[1] All peat was applied on an ovendry weight basis. The fertilizers used were 20-percent ammonium sulfate, 20-percent superphosphate, 50-percent muriate of potash, 15–30–15 Nitrophoska, and ordinary commercial aluminum sulfate.

TABLE 19.—*Effect of soil amendments on size of 2–0 Colorado blue spruce, Towner Nursery, Towner, N. Dak.*

Treatment per square foot of bed	Trees per square foot at 2–0 age	Length: Top	Length: Root	Stem diameter	Green weight per plant	Top-root ratio based on weight
	Number	*Inches*	*Inches*	*64ths inch*	*Grams*	
None	21.6	1.8	7.5	3.3	0.98	1.00
Three-eighths ounce of sulfuric acid (diluted)	14.2	3.1	7.3	4.8	2.12	1.09
One-fourth ounce of 15–30–15 Nitrophoska	21.5	1.9	6.6	3.3	1.04	1.00
Three-eighths ounce of sulfuric acid plus 1 pound of mycorrhizal soil	20.7	3.0	7.1	5.2	2.40	1.07
Three-eighths ounce of sulfuric acid plus one-fourth ounce of 15–30–15 Nitrophoska plus 1 pound mycorrhizal soil	18.6	2.8	7.6	4.7	1.99	1.31

Nitrogen.—Nitrogen has been applied to the soil at the time of ground preparation. Application has usually been at the rate of 40 to 80 pounds per acre, usually in the form of 20 percent ammonium sulfate (200 to 400 pounds per acre). Sometimes it is applied in a complete fertilizer, such as 600 pounds per acre of 15–30–15 or 15–35–15. When applied at moderate amounts in properly modified soil, adequate stands were obtained.

Overtreatment with concentrated nitrogen fertilizers can cause increased damping-off or actual chemical injury and may reduce the tree stand (fig. 44).

Sodium nitrate applied as a preseeding treatment greatly reduced a stand of 1–0 ponderosa pine. For treatments of 0, 400, 800, and 1,200 pounds per acre, the stands per square foot were 54, 31, 20, and 18 seedlings, respectively.

When beds are acidified at the time of fertilization with nitrogen-supplying materials rototilled into the soil, losses from subsequent damping-off are minimized. This point is discussed in a succeeding section on maintenance of proper pH.

Phosphorus.—Phosphorus often is the key element in short supply. When applied at 340 to 680 pounds per acre of 20-percent superphosphate, it has given good response. In fact, in some trials as much as 1,320 pounds per acre was used with optimum response. Phosphorus is also applied in mixed fertilizers. At most nurseries, use of 600 to 800 pounds per acre of 20 percent superphosphate has been sufficient, even for the most deficient situations.

Potassium.—If required, about 100 to 200 pounds of potassium sulphate can be supplied.

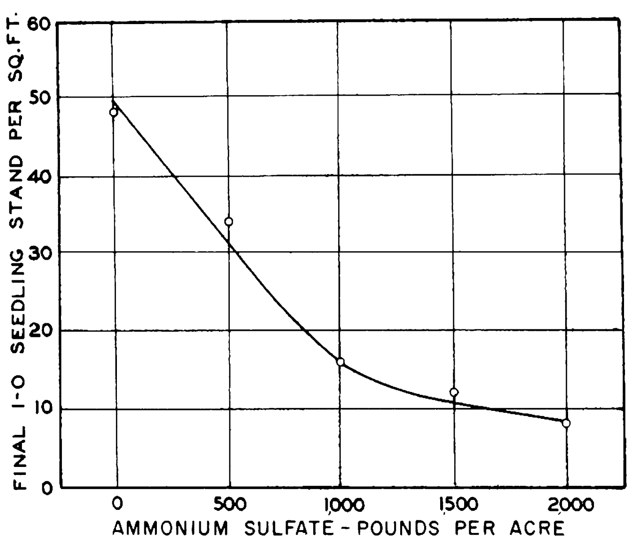

FIGURE 44.—This graph shows an example of heavy treatments of nitrogen fertilizers. A small-scale experiment using 20-percent ammonium sulfate worked into the top 6 inches of soil before seeding on June 9 caused a reduction in 1–0 ponderosa pine tree stand due to damping-off and chemical injury. The beds had not been acid treated. Stand differences are highly significant statistically. Towner Nursery, Towner, N. Dak.

Calcium and magnesium.—Calcium or magnesium has not been deficient in Prairie-Plains conifer nursery soils. In fact, an excess has sometimes been a problem.

Iron.—Iron sulfate can be applied as a 1-percent foliage spray to wet the needles thoroughly in case of mild chlorosis (Korstian et al. 1921), in amounts of about 25 pounds per 50 gallons of water per acre (Imperial Institute of London 1936), or with more massive doses of 680 pounds or more per acre applied as a powder at time of seeding or in solution on established beds. Use of iron chelates has definite potential for correcting chlorosis (Haertl 1955, Stewart and Leonard 1952). For some horticultural crops, application of iron chelates, at 5 to 10 pounds per acre, has been effective in correcting chlorosis. Often much heavier treatments are necessary, and the treatment may be quite costly, especially if 20 or more pounds should be required per acre. There is little or no experience regarding the value of chelates on coniferous nurseries in the Prairie-Plains.

Manganese.—This element can be supplied as a manganese sulfate powder, disked in before seeding. In one experiment its application, at 340 pounds per acre, doubled the ponderosa pine tree stand at the 1–0 and 3–0 stages (apparently due to damping-off control) but did not increase growth. The Imperial Institute of London (1936) mentions its use, at 50 to 100 pounds per acre, as early as 1936.

Useful references on soil fertility include those of the Chilean Nitrate Educational Bureau, Inc. (1948), Mayer-Krapoll (1956), Stoeckeler and Arneman (1960), White and Leaf (1956), and Wilde (1958).

LIQUID FERTILIZERS AS TOPDRESSINGS

Liquid fertilizers have been applied as topdressings in early June on offcolor beds with some success. Among those that have given good results are (1) one-eighth ounce of 15–30–15 fertilizer per square foot applied in June on 2–0 blue spruce (fig. 45); (2) one-fourth ounce of 11–48–0 ammonium phosphate per square foot applied in June on 3–0 white spruce; and (3) one-twelfth to one-eighth ounce of 20-percent ammonium sulfate per square foot on first- or second-year pines or spruces. At the Bessey Nursery on 2–0 stock, urea has been found effective when applied in early June in a dilute solution at 0.042 ounce of urea per square foot (equivalent to 50 pounds of nitrogen per acre).

Liquid fertilizers generally are not applied more than once a year; however, at the Bessey Nursery 2–0 stock has sometimes received two treatments; each time 0.092 ounce of 20-percent ammonium sulfate per square foot was used. Regardless of the type of liquid fertilizer used, overhead irrigation should follow immediately after treatment to wash the fertilizer off the foliage and prevent fertilizer burn.

Liquid fertilizers can be pumped through the overhead system or applied from an acid barrel. In the

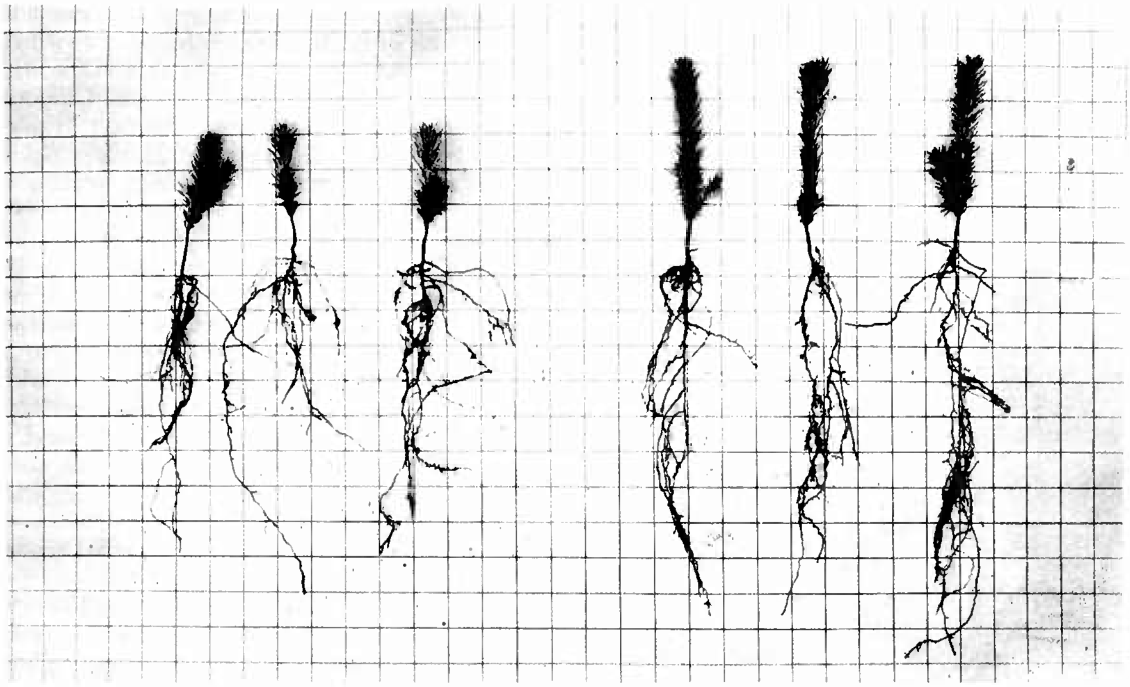

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FIGURE 45.—Liquid fertilizers can improve the growth and color of the seedlings. These are 3–0 blue spruce at Towner Nursery, Towner, N. Dak. At left, three trees from an unfertilized bed; at right, three trees from a bed given a liquid topdressing of one-eighth ounce of 15–30–15 fertilizer per square foot of bed in June of the previous season.

latter case, the water-soluble fertilizer is placed in a sack and hung in the acid barrel to prevent clogging of the holes in the pipe.

MANURE, COMPOST, LEAF MOLD, AND PEAT

Bulk organic matter has been used with considerable success in the Plains nurseries. Animal manures are most often used; however, various composts are also applied, and development of a peat supply may have promise in the north.

The chernozemic soils of the Northern Plains are generally rather well supplied with humus (Nikiforoff 1938), but prolonged cropping gradually depletes it. Regular application of farm manures in crop rotations is the best means of reducing the rate of nitrogen depletion (Haas and Evans 1957). The beneficial long-range effect of farm manures has been well documented (Haas and Evans 1957, Salter and Schollenberger 1938, Van Slyke 1932). However, if animal manures are used, application should be confined to cover crops or transplants or as an ingredient in compost since their use may accentuate the damping-off and weed problems. They should be left in the compost pit for at least 1 year before use in the nursery. Application of 20 to 40 tons per acre has produced excellent results.

At the Bessey Nursery, until 1953, a compost was made up of 2,000 pounds of weeds, grass, or other vegetative material, 25 pounds of ammonium phosphate, and 300 pounds of calcareous clay. The clay and fertilizer were mixed and layered between the weeds and kept moist. This material, slightly richer than barnyard manure, was composted for 2 years before 20 tons per acre was applied just before the rye cover crop was plowed under.

In the Southern Plains, higher rainfall intensities, higher temperatures, and a longer warm season deplete the humus reserve more rapidly than in the north, and the use of bulk organic matter (animal manures or composts) in the nursery becomes even more necessary. Here there is prospect of using straw, and sawdust in the more easterly areas, as an ingredient in making composts (Allison and Anderson 1951, Feustel 1938).

Leaf litter has been an excellent material for soil improvement in nurseries in forest regions (Lanquist 1945, Wilde 1946). Leaves that have been raked up from trees along streets have also been used to advantage (Stoeckeler and Jones 1957). Leaf mold can sometimes be obtained in the Prairie-Plains from natural stands in bottomlands or hill areas.

Peat deposits with organic matter that can be added to nursery soils can occasionally be found in the Northern Plains. These peats tend to have a high pH level. The range in one bog near Towner, N. Dak., was 6.0 to 7.6, and in most places the pH was about neutral. This peat, when used experimentally at 10, 25, and 50 tons per acre on new seedings of ponderosa pine without acid treatment of the beds, had no deleterious effect on the tree stand. An application of sheep manure, however, drastically reduced the stand from 58 to 22 trees per square foot, and seeding density, from 38 to 14 (fig. 46). The loss was due to damping-off.

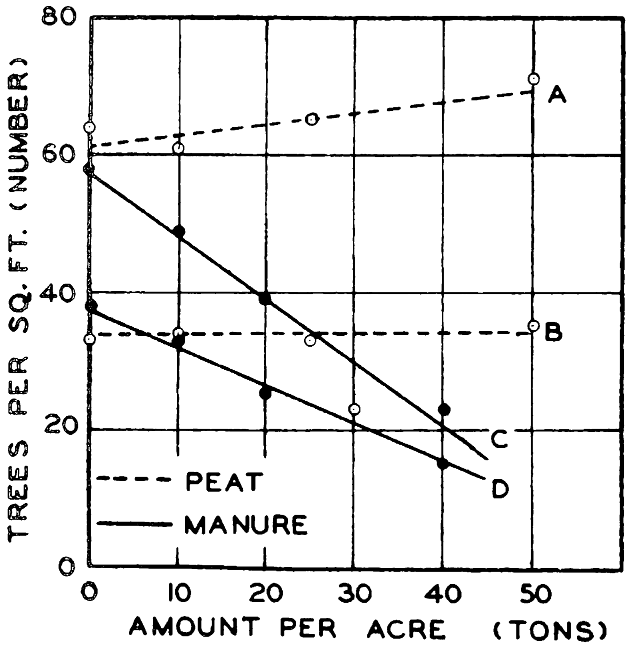

FIGURE 46.—Comparison of 1–0 stands of ponderosa pine as affected by two rates of seeding and by the application of various amounts of moderately acid peat (*A* and *B*) and sheep manure (*C* and *D*) to beds just before seeding. No acid treatment was used. *A* and *C* were sown at the rate of 116 viable seed per square foot. *B* and *D* were sown at 58 viable seed per square foot. The peat treatments had no adverse effect on the stand. The manure was highly deleterious (at a 1-percent level of significance). Towner Nursery, Towner, N. Dak.

COVER AND SOIL IMPROVEMENT CROPS

Many Plains nurserymen use a cover crop at least once every 3 or 4 years in the rotation. Cover crops have three primary purposes: (1) To prevent soil blowing on land not occupied by trees, (2) to add organic matter, and (3) to keep the weed problem reasonably controlled on land without trees.

Cover crops used commonly in the Prairie-Plains conifer nurseries are Hubam clover, soybeans, biennial sweetclover, rye, oats, sweetclover, field peas, cowpeas, and vetch or a rye-vetch mixture. Hubam clover has been used in the Dakotas, and cowpeas and soybeans in the Central and Southern Plains.

Cover crops that are hosts to various nematodes should not be used. An example is the soybean cyst nematode found in States east of the Prairie-Plains. This nematode is difficult to eradicate from infected fields, and stock from such fields likely would be quarantined.

Leguminous cover crops may add as much as 100 to 150 pounds of nitrogen per acre; they also may supply several tons of organic bulk per acre (Chadwick 1938; Pieters and McKee 1938; Rogers and Giddens 1957).

Cover crops require some irrigation in dry periods and may require fertilization. The legumes, particularly, cannot be expected to produce worthwhile crops without some supplemental water.

Cover crops are plowed under shortly before or during the first development of flowers, or they may be mowed at that time so that seed formation can be avoided and an erosion-preventing mulch can be retained on the surface. Rye is often seeded in late summer in paths and at bed ends as well as on fallow land. It creates enough cover to give good overwinter protection. All cover crops should be plowed under 4 to 6 weeks in advance of seeding. Many nurserymen prefer to use them in the rotation before transplanting rather than before seeding.

In North Dakota nurseries, biennial white sweetclover is sometimes sown in May of one year, and plowed under in May or June of the following year.

In Canadian nurseries, under semiarid conditions, cover crops such as millet, rye, Sudangrass, and barley all produced 2 to 4 tons of dry material per acre when given several inches of irrigation (Knight 1956).

At the Bessey Nursery in Nebraska, the policy is to use a cover crop every third year. Whippoorwill cowpeas are sown at the rate of 1½ bushels per acre in early May and plowed under in late July or in the early blossom stage; the area is left fallow until early September and then sown to winter rye. Sometimes rye can be a problem following its incorporation into the soil because incompletely decomposed plant residues tend to interfere in subsequent seeding or planting. Oats may be superior to rye in this situation.

The amount of organic matter and nitrogen supplied by a cover crop is rather small compared with that furnished by the usual 10- to 20-ton treatment per acre of compost or manure. In many instances excellent crops of trees have been grown for a prolonged period without use of a cover crop. For example, at the Towner Nursery, one tract without cover crops was used continuously for 10 years and each tree crop was more vigorous than the previous one. Organic matter in the form of manure was used liberally.

MAINTENANCE OF PROPER pH

The pH of the soil is an expression of its relative acidity or alkalinity.[18] Many agricultural plants grow quite well over a wide range of pH, often 5.0 to 8.0, while others require a soil well supplied with lime and preferably slightly alkaline (Allaway 1957).

[18] A soil with a pH of 3.5 would be considered extremely acid; about 5.0 to 6.0, moderately acid; 7.0, neutral; 7.5 to 8.0, moderately alkaline; and 8.5 to 9.0, extremely alkaline. Very acid soils are low in lime, while very alkaline soils (above pH 8.5) have an excess of salts or alkalies which adversely affects physical characteristics and water relations of the soil and may depress or kill plant growth.

The maintenance of the proper pH of the soil is very important in Plains nurseries. Serious errors can result in extremely high costs per thousand salable trees or even in stand failure.

Among conifers commonly grown in Prairie-Plains nurseries, eastern redcedar, Rocky Mountain juniper, and Siberian larch grow well in circumneutral soils at a pH of 6.0 to 7.5. Ponderosa and Austrian pines have done well at a pH of 5.5 to 7.2, and white spruce, blue spruce, jack pine, and Scotch pine have grown best in a moderately acid soil of about 5.5 to 6.5.

Broadleaf species generally tolerate more alkalinity than do conifers (Stoeckeler 1946), and young conifer seedlings tolerate less than transplants or older stock.

The chief problem encountered in Plains soils is alkalinity. An inherently high content of carbonates is accentuated by additional carbonates in irrigation waters. The problem is more acute if the nursery soil has poor internal drainage. Often soils that were slightly acid (6.2 to 6.5) before irrigation have a pH change to 7.5 to 7.7 after 1 or 2 years' irrigation, with great subsequent harm to the conifers because of serious damping-off, root rot (Davis 1940), and phosphate and iron starvation. Truog (1946) states that the availability of phosphorus, iron, manganese, zinc, copper, and boron all are greatly reduced when soil pH is moderately alkaline. Treating the soil with acidifying materials such as sulfur may make iron more available (Holmes and Brown 1957). Bjorkman (1953) noted potash starvation in spruce on soils with a pH up to 7.6 and reported that mild cases were corrected by acidification.

Tests of the pH of the top 6 inches of soil should be made in a number of places to determine the probable amount of acidification required. Acidification should not be overdone, and apparently there is no need to lower the pH below about 5.3 to 5.5 in Plains conifer nurseries. When the soil acidity is lowered to a pH of about 3.8 to 4.5, magnesium and calcium deficiencies may result (Voigt, Stoeckeler, and Wilde 1958).

COMPARISON OF ACIDIFICATION WITH DIFFERENT CHEMICALS

The alkalinity of conifer seedbeds cannot be corrected satisfactorily by the usual fertilization practices. The soil must be acidified. Such treatment will greatly enhance the effects of fertilizers applied later and will improve the rate of spread of beneficial mycorrhizal fungi.

To test the effectiveness of several chemicals in correcting soil alkalinity by acidification, an experiment was conducted on a loamy sand soil at the Towner Nursery in 1938. Seedbeds of ponderosa pine were treated in the spring at the time of seeding and retested in the fall of the same year. All chemicals were applied in solution, using about 1 pint of water per square foot of seedbed.

Five chemicals (sulfuric and phosphoric acids, and aluminum, iron, and manganese sulfates) were tested at three soil depths (figs. 47 and 48).

In the spring of 1938, the top 8 inches of the untreated soil had a pH of 6.8; in the fall of the same year, after one season of irrigation, it was 7.5 for the surface 4 inches and 7.2 for the 4- to 8-inch level. Except for the weakest solutions, the applications greatly reduced the pH of the surface 2 inches of soil and somewhat reduced the 2- to 4-inch and 4- to 8-inch depths.

Considering the vigor and size of seedlings and the ultimate stand obtained, it was concluded from this and other tests that a safe, effective, and consistent treatment consisted of application of one-fourth to three-eighths fluid ounce of sulfuric acid or one-half avoirdupois ounce of aluminum sulfate per square foot for a moderately alkaline soil condition. The degree and persistence of the acidification obtained and the damaging effects on the trees were considered in this evaluation. For subsequent re-treatment of areas where previous crops had been acidified, often one-eighth to one-fourth fluid ounce of sulfuric acid or one-fourth ounce aluminum sulfate was sufficient.

In addition to the five chemicals mentioned, sulfur in fine powder form was also applied before sowing. It proved to be very effective at one-fourth to three-eighths ounce per square foot for a first application in sandy soils and at one-half ounce per square foot on alkaline silt loams (Stoeckeler and Arneman 1960). In applying this treatment, any lumps in the material must be thoroughly pulverized since acid injury may occur if rootlets of plants contact grains or chunks of the sulfur. In terms of acidifying power, 7 avoirdupois ounces of sulfur has about the same effect on pH as 10 fluid ounces of sulfuric acid (Davis, Wright, and Hartley 1942).

Flowers of sulfur tend to produce less acid injury if applied several months or a year before the germination period. However, they have been repeatedly used in a large number of experiments immediately preceding spring seeding, with no apparent acid injury and with great benefit to the growth of the more lime-sensitive tree species. In all cases the material was very well pulverized and free from grains as large as a match head.

Sulfur can be expected to be effective for a prolonged period. For instance, the effect of a heavy treatment at the Towner Nursery in 1935 lasted until the fall of 1941, when some treated areas were still in the 5.1 to 5.6 pH range. This prolonged effect is due to the slow chemical reaction and the fact that less sulfur than sulfuric acid is leached out in irrigation water.

Some treatments of one-half fluid ounce of concentrated acid per square foot, diluted to about 2 percent in water, have subsequently injured seedlings. Therefore, it is recommended that the amount of acid not exceed three-eighths fluid ounce.

Before application, the number of square feet of the seedbed to be treated is determined. The required

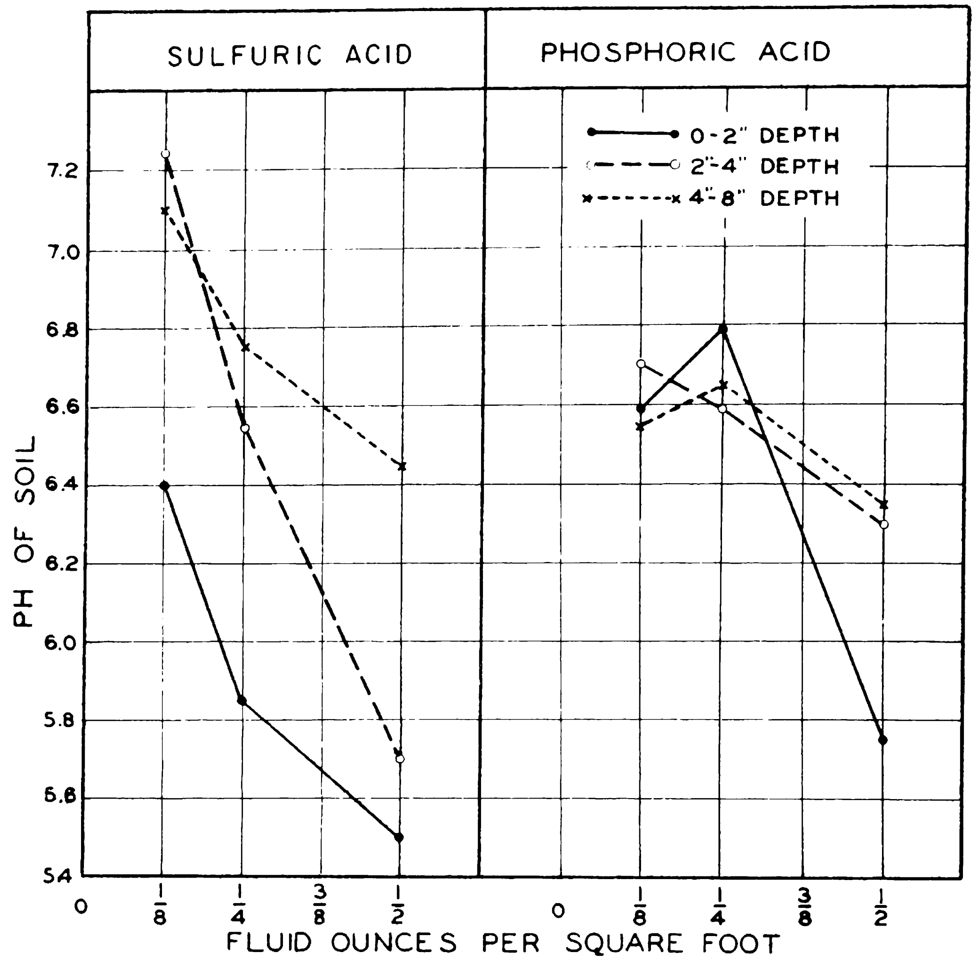

FIGURE 47.—Effect on soil pH of sulfuric acid and phosphoric acid. Applications were made in the spring of 1938, and the soil tests were made in the fall of the same year. Towner Nursery, Towner, N. Dak.

amount of concentrated acid is calculated by multiplying the desired dosage (expressed in fluid ounces per square foot) by the number of square feet. This amount is then diluted to 2 percent by volume to avoid injury to the trees. The solution is applied so that all of the treated area will receive approximately the same amount.

As noted previously, species vary in their pH preference or their tolerance of alkalinity. The lower dosages (about one-eighth fluid ounce per square foot) often sufficed for ponderosa pine. Jack and Scotch pine and all the spruces required the heavier treatments for best results. At the Towner Nursery, jack pine beds had eight trees per square foot in untreated second-year beds (pH about 7.5) while the beds treated with one-fourth and three-eighths fluid ounce of sulfuric acid per square foot averaged 30 and 51 trees, respectively (fig. 49). Untreated beds were chlorotic; treated beds were a healthy green, and average heights were double those of the untreated beds. The three-eighths ounce treatment gave the best results at the 2–0 stage.

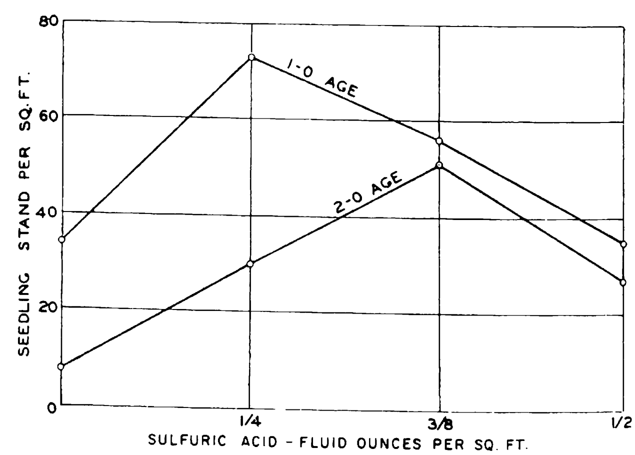

FIGURE 49.—Effect of sulfuric acid treatment of beds at the time of seeding on resulting stands of jack pine at 1–0 and 2–0 age. The seeding rate was 132 viable seeds per square foot. The acid was applied in water solution at the rate of about 25 cubic centimeters of sulfuric acid per gallon of water. Towner Nursery, Towner, N. Dak.

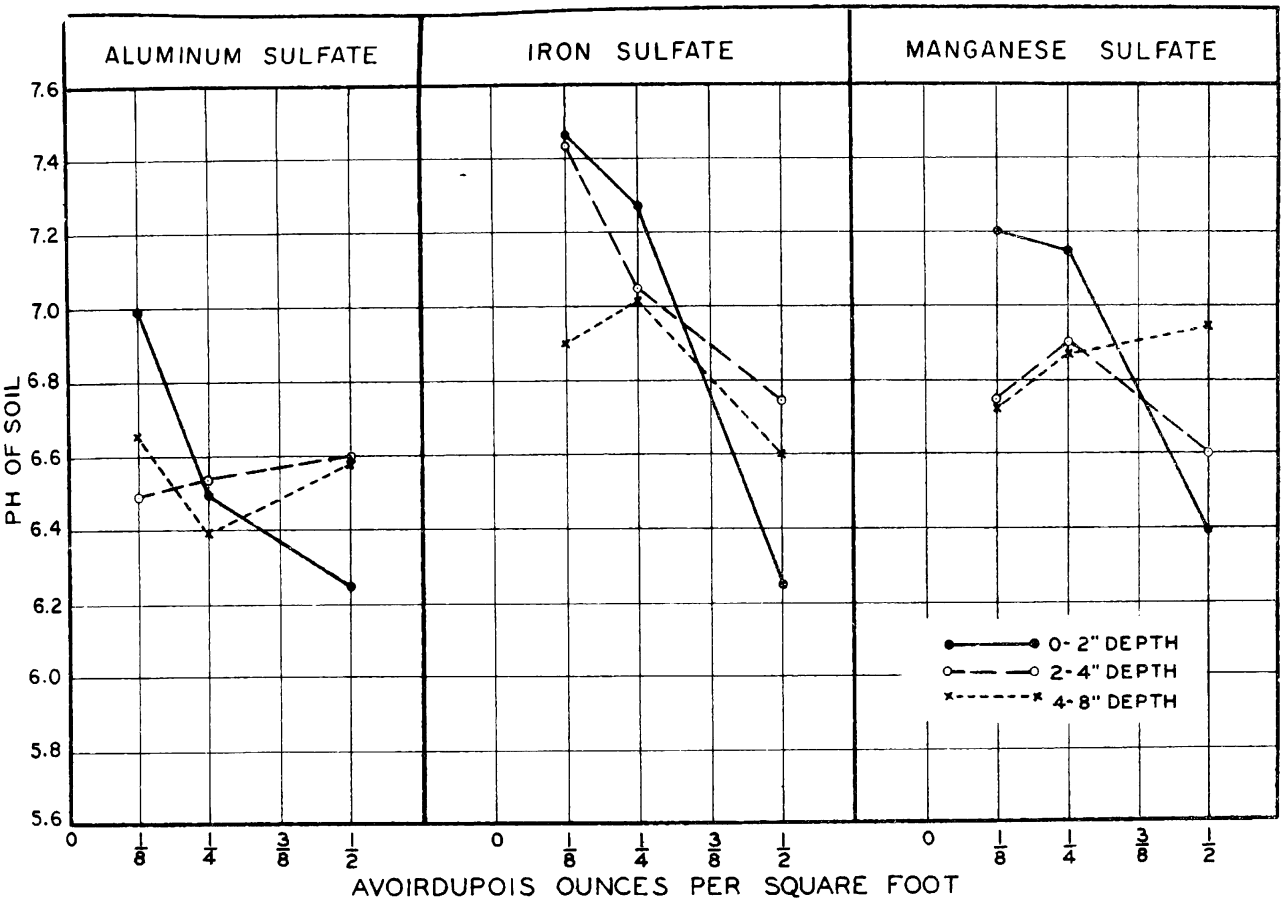

FIGURE 48.—Effect on soil pH of aluminum sulfate, iron sulfate, and manganese sulfate. Applications were made in the spring of 1938, and soil tests were made in the fall of the same year. Towner Nursery, Towner, N. Dak.

Similar results were observed in blue spruce; with this species the application of three-eighths fluid ounce of sulfuric acid per square foot doubled the weight of second-year trees. In several North Dakota nurseries, application of one-fourth fluid ounce of sulfuric acid doubled or tripled the number of usable plants produced per square foot. Results for flowers of sulfur were similar.

Variable response has been obtained in juniper seedbeds.

The response to commercial-grade aluminum sulfate also varied by species; ponderosa pine had an optimum stand when one-half ounce per square foot was applied; comparatively greater effect was obtained at higher rather than low sowing rates (fig. 50). In a trial in which 0, ½, 1, and 1½ avoirdupois ounces were used (fig. 51), the 1-ounce treatment per square foot gave the best stand of jack pine. The average heights for 2–0 trees were 1.2, 1.5, 2.0, and 2.0 inches, respectively. Color was not as good as in the sulfuric acid treatment. In the presence of an adequate phosphate

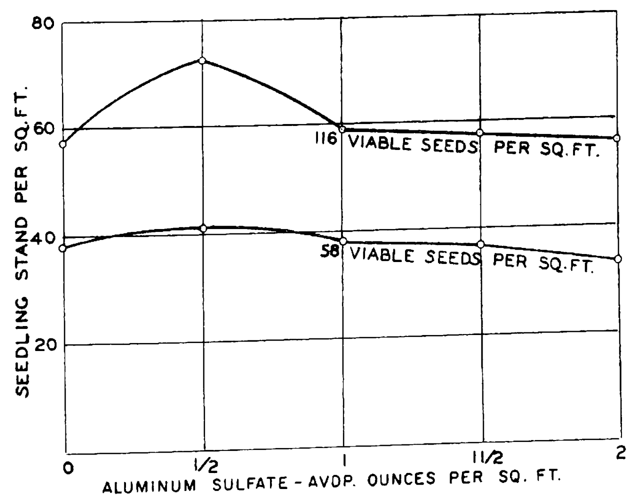

FIGURE 50.—Effect of aluminum sulfate treatment on first-year ponderosa pine seedbug stands at two densities of seeding. The chemical was raked into the top 2 inches of soil before seeding. Towner Nursery, Towner, N. Dak.

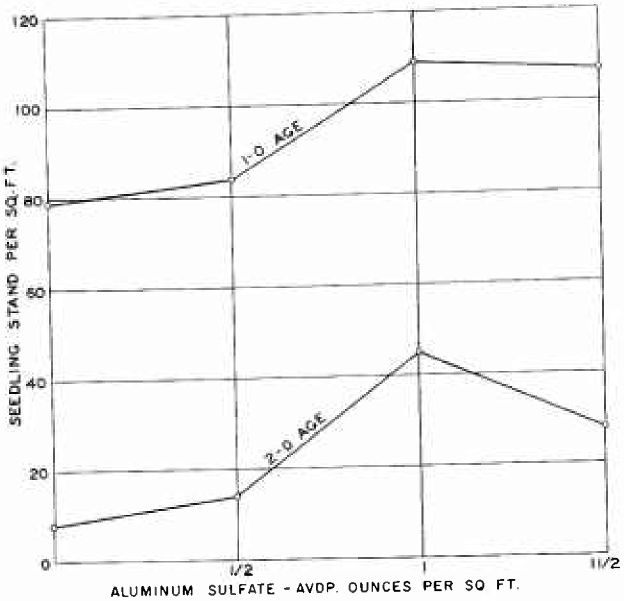

FIGURE 51.—Effect of aluminum sulfate treatment on stand of jack pine seedlings. The seeding rate was 132 viable seeds per square foot. The material was applied dry on newly seeded beds and washed into the soil by heavy sprinkling immediately after application of the chemical. Towner Nursery, Towner, N. Dak.

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FIGURE 52.—Application of dilute solution of sulfuric acid to seedbeds. Bessey Nursery, Halsey, Nebr.

level, on some occasions acidification did not increase the number of ponderosa pine trees.

Hartley (1915, 1917) did some of the early research in damping-off control at the Bessey Nursery and other nurseries. He found a marked increase in tree stand and size from acid treatment and warned against injury from concentration of acid as the surface soil dried.

Another important benefit of soil acidification is weed control. Hartley (1915) reported substantial weed control by sulfuric, nitric, and hydrochloric acid. Hartley's results were verified many years later at the Towner Nursery where the weed stand for a 1-month period after acidification was reduced substantially:

Treatment	*Chemical per square foot (ounces)*	*Weed stand per square foot (number)*
Control, untreated	0	40
Aluminum sulfate	½ avdp. oz	45
Do	1 avdp. oz	37
Do	1½ avdp. oz	29
Do	2 avdp. oz	28
Sulfuric acid	⅛ fluid oz	40
Do	¼ fluid oz	27
Do	⅜ fluid oz	20
Do	½ fluid oz	13

Acidifying materials such as sulfuric acid or phosphoric acid in about 2 percent solution are generally applied from an acid barrel immediately after seeding. A wooden barrel, steel drum, or lead-lined container drawn by hand or by tractor is used (fig. 52).

Aluminum sulfate may also be applied in solution with an acid barrel or cart. Such an application gives somewhat better damping-off control in the critical surface inch or two of soil, but it does require slightly more labor and expense than when the aluminum sulfate is applied dry with a fertilizer or lime spreader.

Acidification to maintain proper pH of the soil has been a common requirement in Plains nurseries. If soil testing indicates a need for acidification, a safe, effective, and consistent treatment is the application of one-fourth to three-eighths fluid ounce of sulfuric acid or one-half avoirdupois ounce of aluminum sulfate per square foot for a moderately alkaline soil condition.

CARRYOVER EFFECT OF ACIDIFICATION

Part of the beneficial effect of acidification may last for more than 3 years. Tests of the soil pH will indicate how much the aftereffect of an initial, rather heavy acidification has persisted. This will vary widely, depending on the amount and quality of the irrigation water used and the tree species involved.

In the fall of 1941, a great variation was observed in some beds of 3–0 Scotch pine at the Towner Nursery. These beds were part of an area which, in the spring of 1936, had been devoted to an experiment involving various levels of acid treatments including no treatment. The beds were sown to Scotch pine in the spring of 1939 without any additional soil treatment.

The extreme variation noted in size of the 3–0 Scotch pine in the fall of 1941 was correlated with the

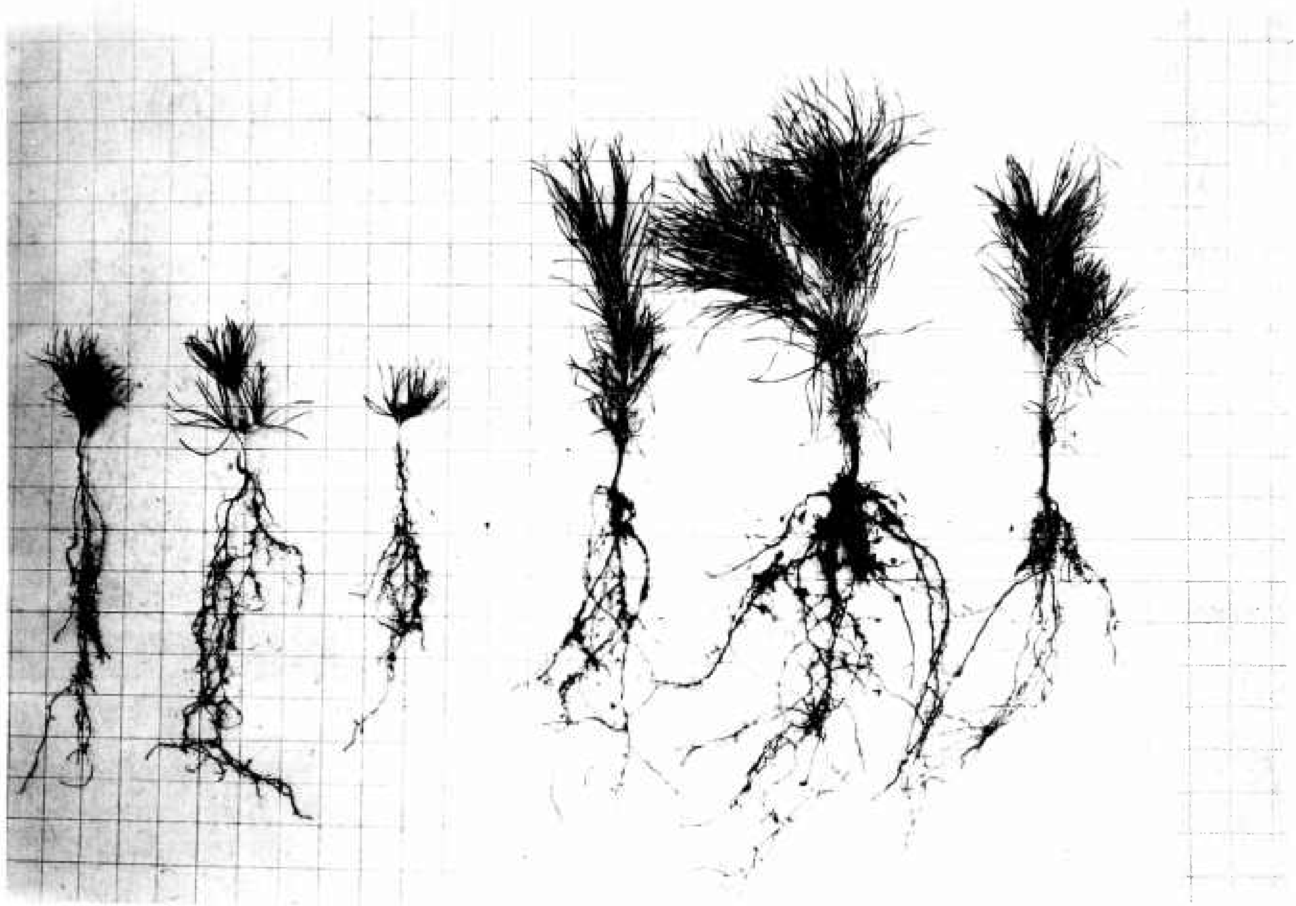

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FIGURE 53.—Difference in size of 3–0 Scotch pine due to treatment of the soil with sulfuric acid 6 years previously. At left, three puny nonmycorrhizal seedlings from untreated areas. At right, three large mycorrhizal seedlings from a plot treated with acid. Towner Nursery, Towner, N. Dak. (One-inch squares are in background.)

acidification treatment of the spring of 1936. The better and larger trees were in the areas which had been most heavily acidified, and the poorest trees were in control beds which had received no acid treatment in 1936.

Samples of the 3–0 Scotch pine, when examined after digging, showed a heavy fungus mantle of mycorrhizal development covering the roots of the good trees. The trees from the areas of poorest development had few or no mycorrhizal fungi and few or no lateral buds surrounding the terminal bud. The contrast in the extremes of the two conditions is shown in figure 53. Similar and striking benefits from acidification were observed on ponderosa pine grown on an alkaline silt loam at Bottineau, N. Dak. (Stoeckeler and Arneman 1960).

The beneficial effect is attributed to the rapid spread of mycorrhizal fungi in the acidified beds and to the improvement in conditions for phosphate and iron assimilation in the same beds.

THE ROLE OF MYCORRHIZAL FUNGI

Mycorrhizal fungi are organisms that live in association with conifers and some hardwoods (Bergemann 1956, McArdle 1932, Melin 1927, Shemahanova 1957). The mycelia of such fungi are intimately associated with the living tissues of the roots, permitting movement of soluble carbohydrates from tree to fungus, and translocation of mineral nutrients from the fungi into the tree roots. The end result usually is increased tree vigor and growth (Wilde 1958).

According to Goss (1960), the occurrence of mycorrhizal fungi on pines, chiefly ponderosa, in Nebraska is relatively sparse in the early spring, compared to their reported occurrence at this season in the forested areas of the Eastern United States. However, he found them on pine roots growing in a wide variety of soils in field shelterbelts, in the sandy soils of the Nebraska National Forest at Halsey, and in several nursery soils. Plains areas or tracts devoid of tree growth for a long period are likely to have no mycorrhizal fungi (Dale and McComb 1955, Goss 1960, McComb 1943, Rosendahl 1942, White 1941). If present, they may be unevenly distributed. The lack of or incomplete distribution of mycorrhizal fungi has been associated with early poor development of some of the conifers used in windbreak planting (fig. 54).

Between 1933 and 1938, an extensive series of experiments with mycorrhizal inoculations and supplementary treatments was conducted at Denbigh, Towner, Oakes, and Bottineau, N. Dak. It was concluded that ponderosa pine was favorably affected in some instances by mycorrhizal fungi, particularly where pH adjustments had been made by acidification; and that Scotch and jack pine and blue and white spruces consistently required mycorrhizal inoculation and acidification with sulfuric acid if they were to have good growth (fig. 55).

Increased growth and lessened chlorosis of ponderosa pine seedlings resulted from the addition of duff-soil inoculum to nonmycorrhizal virgin grassland soils (Goss 1960). More mycorrhizal than nonmycorrhizal seedlings were able to survive a rapid and extreme soil moisture deficiency.

Some studies in 1936 included inoculation of beds with pure cultures or mycorrhizal nursery soil. These tests demonstrated clearly that the specific mycorrhizal fungi involved did not thrive in an alkaline soil (pH about 7.5). However, when the soil was acidified sufficiently to lower pH to 6.0, they grew well.[19]

Mycorrhizal fungi can be introduced into prairie and plains soils by one of several methods:

1. Incorporation of leaf mold, humus, and surface soil (surface 2 to 3 inches) from a well-established plantation or shelterbelt of spruce or pine or from a natural stand.
2. Incorporation of surface soil from a well-established nursery that is free from the more serious disease and insect pests and has nursery stock showing an abundance of mycorrhizal fungi.
3. Incorporation of compost made of stockpiled leaf mold and peat containing mycorrhizal fungi over the nursery beds.
4. Transplanting some pine or spruce seedlings obtained from a nursery where the mycorrhizal fungi on the seedling stock are abundant.

The more successful of these methods has been the use of mycorrhizal soil or seedlings from natural stands

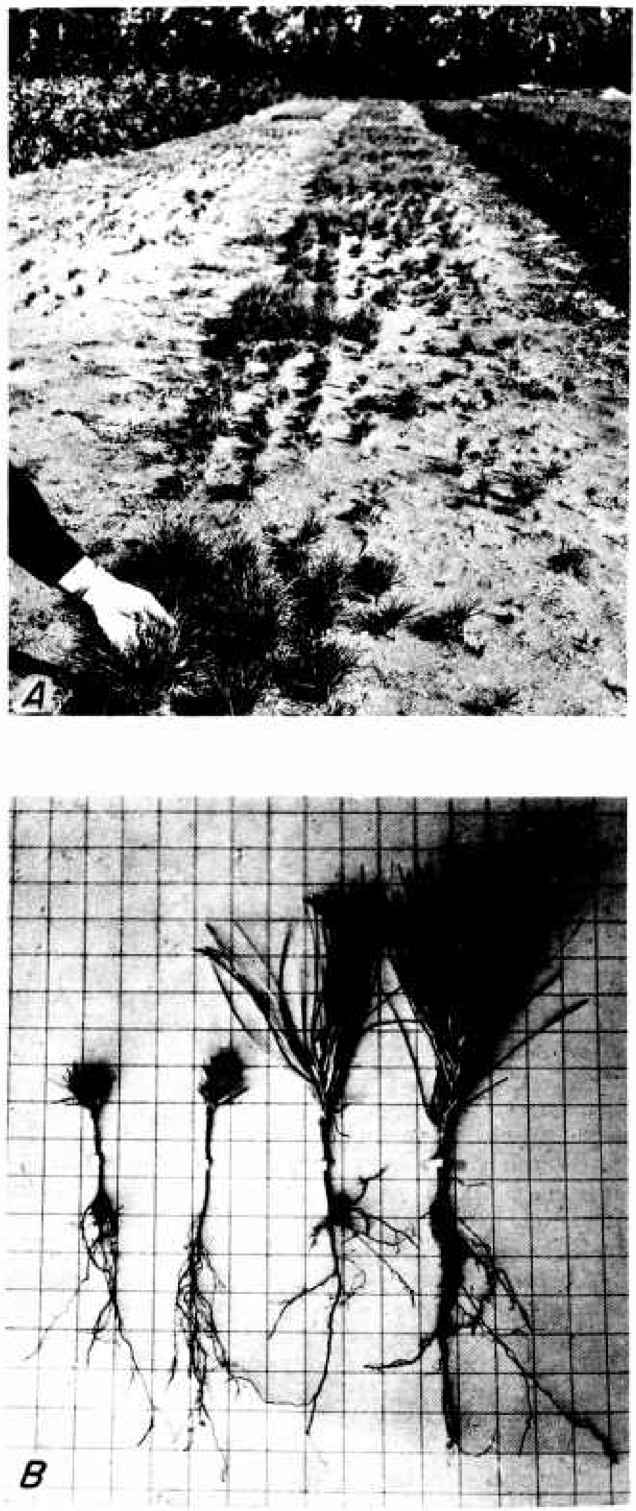

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Figure 54.—*A*, Patchy, uneven condition of second-year untreated beds of ponderosa pine in a North Dakota nursery caused by uneven distribution of mycorrhizal fungi and aggravated by soil alkalinity. *B*, Closeup of mycorrhizal (right) and nonmycorrhizal (left) seedlings lifted from good and poor areas in the above nursery. (One-inch squares are in background.)

[19] The pure cultures were supplied by Dr. K. D. Doak of the then Bureau of Plant Industry, Washington, D.C. Wheat was boiled 4 hours and then cooled before inoculation with specific strains of mycorrhizal fungi and other fungi. These spread throughout the glass jar container within 4 to 6 weeks after inoculation. The species used included: *Boletus granulatus*, a mycorrhizal fungus found beneficial to certain conifers native to or introduced into the Eastern United States (including Scotch, eastern white, jack, pitch, and red pine); *Ithyphallus ravenelii*, a nonmycorrhizal fungus which, according to Dr. Doak, has benefited Scotch pine and some spruces and firs; *Clitopilus abortivus*; and *Hypholoma uda*. On subsequent evaluation, the last two were deemed of little value.

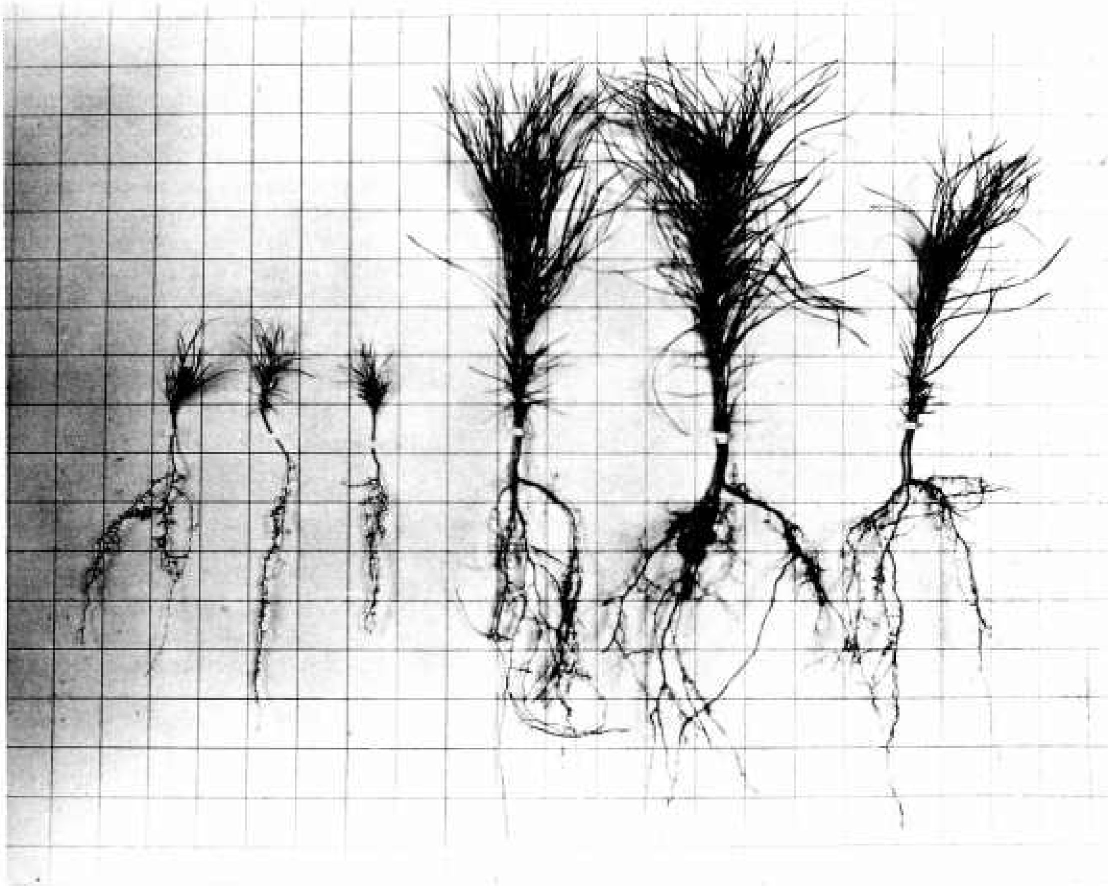

FIGURE 55.—Jack pine (2–0) seedlings showing effect of mycorrhizal soil and acidification treatment. Trees on the right received one-fourth ounce sulfuric acid, 1 pound of mycorrhizal soil, and one-fourth ounce of 15–30–15 fertilizer per square foot of seedbed. (One-inch squares are in background.)

or an established nursery, or the use of leaf mold and surface soil from a shelterbelt of pine or spruce. It will require at least 1 or 2 bushels of mycorrhizal soil or leaf mold per 100 square feet of seedbed to obtain any semblance of uniform inoculation; in order to use this amount, the material must be kept moist in transit, an acid soil condition (pH around 6.0) at the new nursery site must be achieved or maintained, and the inoculum must be spread very uniformly and disked into the surface 2 inches, and then the soil must be watered.

The safest procedure (the one that will introduce the least disease and the fewest insect pests) would be to obtain the leaf mold and surface soil from a natural pine or spruce stand. However, these are sometimes so distant that the material must be obtained from a planted stand or shelterbelt. If soil that contains mycorrhizal fungi from old nurseries or distant localities is used to inoculate a new site, it should be clearly free of insects, diseases, and nematodes. However, moving of soil or plants from one nursery to another is not generally recommended as a means of transferring mycorrhizal fungi.

The introduction of pure cultures of mycorrhizal fungi requires more research before it can be recommended for large-scale operations.

Mycorrhizal fungi are capable of maintaining themselves in soils where the host plants are absent for several years (Rosendahl and Wilde 1942). At the Towner Nursery, fungi lasted very well without a coniferous host plant from 1943, when the nursery went out of production, until 1953, when it was reactivated without reinocultaion of the beds. Even the first crop of spruce and pine produced after the 10-year lapse appeared to be abundantly supplied with appropriate mycorrhizal fungi, and the 2–0 beds in 1954 were quite uniform and of good color. The presence of humus extends their ability to survive (Kelley 1930).

NURSERY PROTECTION

More seedlings are lost or injured from various causes while in the nursery and during distribution than later, when they are in the field. To avoid serious losses from nursery injuries, constant vigilance will be needed, since early discovery is quite as important as prompt treatment.

Protection of seedlings involves guarding against loss by four major factors: Weather, insects, mammals and birds, and diseases. Major sources of injury, as well as some of the minor ones, are described in this section. Some formulas for insecticide and fungicide sprays and for mouse bait are given in the Appendix. Also in the Appendix, under "Sources of Information on Nursery Problems," are suggestions on sources from which additional information on specific problems can be obtained.

METEOROLOGICAL FACTORS

The climate of the Plains is characterized by extremes. Chief among the characteristics influencing the production of coniferous stock is the persistent, rather high wind movement; the low precipitation in the northwest portion furthest removed from the Gulf of Mexico; and the extremely high temperatures which occur everywhere where moisture is lacking at midsummer. While the nurseryman has no control over heat, cold, rain, hail, and wind, he can diminish the effects of all these forces, except hail, by good soil management, timely irrigation, development of effective windbreaks, and other good nursery practices.

Wind

Wind adversely affects seedling production by (1) burying the seed and seedlings or blowing them out of the ground; (2) causing mechanical injury by sweeping along the ground particles of sand that cut the small seedlings near the ground line or that sandblast the tender foliage or cotyledons; (3) accelerating depletion of the soil moisture and making the even distribution of water difficult; and (4) intensifying the drying effect of high temperatures on plant tissue (Engstrom and Stoeckeler 1941). Older stock may be affected by desiccation of the tops, which results in foliage and bud damage and a less attractive appearance. Roots dry out faster if the wind is blowing during lifting operations.

The location of nurseries in naturally protected sites will reduce wind damage. Where this is not possible, protection must be provided by a system of windbreaks. For exterior belts, two to seven rows may be needed. For interior windbreaks, one to three rows should suffice.

The zone of intensive wind protection for good shelterbelts is usually about 10 tree heights. Trees in nurseries with supplemental water and high fertility levels will generally attain effective heights of 40 to 50 feet. The spacing between belts thus can be about 400 to 500 feet.

Nurseries with rather limited space may find it advisable to avoid using cottonwood, Siberian elm, and other species with widespread root systems. It may be better to use one to three rows of conifers in exterior belts and only snow fence for interior portions.

Species that may serve as host or brood trees for insects and mites or as sources of infection for diseases that attack trees being grown in the nursery should be avoided if possible. Eastern redcedar has carried over populations of red spider, with subsequent reinfestation of new seedlings in Nebraska nurseries; and white spruce has done the same in North Dakota. Scale insects and tip moths are examples of insects that may maintain populations on pine in windbreaks and thus infest seedling and transplant beds. Phomopsis blight of junipers may be transmitted from older trees in the nursery to new seedlings.

It is customary to place interior roads next to the windbreaks as much as possible since, even under irrigation, the 15- to 20-foot zone next to such windbreaks is not suitable for nursery stock production because of the sapping and shading effect of the trees. Biennial pruning of the roots during the dormant season will help reduce the sapping effect. The pruning is done 10 to 20 feet from the trees and to a depth of 2 to 2½ feet. It can be done with a root cutter, a chisel subsoiler, or a middlebuster plow modified as a root cutter.

One-row plantings of Siberian elm spaced about 4 feet apart have proved very effective at the Oakes Nursery (fig. 56). The east-west belts are about 175 to 200 feet apart, and the north-south belts are about 400 feet apart.

The presence of at least one or two rows of conifers, particularly a row of pine flanked by a row of another dense-growing species, in exterior or major windbreaks helps reduce wind erosion when broadleaf species are devoid of leaves (fig. 57). Nurseries laid out on the contour may benefit from interior windbreaks paralleling terraces and placed at intervals of about 100 to 200 feet (fig. 58).

Some nurseries use interior hedges of tall-growing shrubs or trimmed cedar. Some Canadian nurseries have trimmed hedges of Siberian peashrubs.

Most nurseries use some slat-wire snow fence placed on pipe supports under pipelines (fig. 59) to reduce sand movement in the interior of blocks. They are especially useful on new sites which have little or no protection by taller tree growth.

The use of annual plants such as sorghum, cane, sunflower, and Sudangrass as temporary windbreaks has been tried in many nurseries in the Plains region. They have not been effective in protecting seedlings because they are not tall enough during the critical period and they sap soil moisture needed by the seedlings in adjacent rows.

(PHOTO COURTESY OF THE NORTH DAKOTA STATE SOIL CONSERVATION COMMITTEE)
FIGURE 56.—Siberian elm shelterbelts at Oakes Nursery, Oakes, N. Dak.

F-475108
FIGURE 57.—This row of 18-year-old ponderosa pine in an exterior shelterbelt is already a substantially effective wind barrier both in summer and winter, Towner Nursery, Towner, N. Dak.

Nursery rows should run at right angles to the prevailing summer wind if the lay of the land permits. Successive rows of transplants will break up the sweep of the wind near the ground.

Heat

Extremely high air temperatures damage seedlings by heating the soil surface at the ground line to a lethal temperature or by causing the tops to transpire faster than their moisture supply from the soil can be replenished. The common occurrence of lesions on the stems of very young seedlings in the Bessey Nursery was early attributed to excessive heating of the surface soil (Hartley 1918).

Heat injury may appear as heat lesions on the stem at the ground line or as a burning of the leaves and succulent tops. Heat cankers have been noted to be more prevalent on seedlings in rows oriented east and west.

In Southern Plains nurseries, trees may be damaged

F-488076

FIGURE 58.—Interior single-row, 6-year-old hedges at the State Nursery, Norman, Okla. These are mostly oriental aborvitae (on right) placed on the downhill slope of each terrace. Multiflora rose (on left) and eastern redcedar were used in a few of the hedges.

F-320779

FIGURE 59.—Slat-wire fences not only protect the soil from blowing and the trees from wind injury but also trap snow. Note relative absence of snow on unprotected field in distance. Towner Nursery, Towner, N. Dak., April 1936.

by heat when hot temperatures and high winds occur in May while the plants are still succulent.

Shirley (1936), in a study of the relative resistance of 1- to 4-year-old conifers of four species to high lethal temperatures in a water bath and under high (85 percent) and low (15 percent) relative humidities, concluded that: (1) Resistance to excessive heat increases with increasing age and increasing size or mass of plant and tissue; (2) tops are more resistant than roots; (3) temperatures as high as 111.7° F., while not causing severe damage to tops in exposures of up to 5 hours, may kill the roots; and (4) there is little difference in the ability of red, white, and jack pine and white spruce to withstand heat. He also found that the external killing temperature for plant material of comparable size and age was higher in air than in water and higher in dry air than in moist air. Bates and Roeser (1924), working with ponderosa and lodgepole pines, Engelmann spruce, and Douglas-fir, also found that the resistance of all seedlings to excessive heat became slightly greater with aging and accompanying hardening of tissues and with an increase in the number of needles. Older plants stand heat better than first-year trees (Shirley 1936).

Beds of 1–0 ponderosa pine at Towner, N. Dak., were injured when the soil temperature at the surface reached 120° F. Baker (1929), in a study of the effect of unusually high temperatures on coniferous reproduction, found that 1- to 3-month-old seedlings of ponderosa pine and Sitka spruce were quickly killed by temperatures of 130°.

Observations by Roeser (1932) of approximate critical temperature maxima that ponderosa pine of different ages can endure may be useful to nurserymen in judging whether to irrigate:

Age in days	*Critical temperature in degrees F.*
58	122
71	133
110	136

He found Douglas-fir and Engelmann spruce were more sensitive to heat injury at 71 days of age than were ponderosa pine or lodgepole pine.

Nursery techniques that will produce sturdy woody stems as early in the season as possible are a logical solution to this problem of heat injury. Older seedlings and transplants shade the soil and reduce the surface soil temperatures.

Irrigation by overhead sprinklers and shading help reduce the damage from heat. In 1936, considerable heat injury was observed on the southwest side of 30- to 50-day-old ponderosa pine seedlings at the Towner Nursery when the soil surface temperatures reached 120° F. or higher. On hot days, the high soil surface temperatures, after one-half hour of watering started around noon, were promptly reduced from a critical temperature of about 125° to below 100° and were held under 120° for 4 hours or longer (fig. 60) (U.S. Forest Serv. Lake States Forest Expt. Sta. 1937).

Adequate stand density may be an important factor in reducing heat losses since seedlings growing close together protect and shade each other. However, other factors besides heat protection must be considered before a decision is made on the number of seedlings to be grown per square foot.

Frost and Winter Damage

Seedbeds generally need to be protected overwinter. In the Northern and Central Plains especially, windburn, winter injury, frost heaving, sudden extreme drops in temperature, and spring and fall frosts are hazards to the seedlings.

In the North it is risky to have succulent trees in the nursery later than September 10. Therefore, well-developed plants must be produced by mid-August in North Dakota and by September 1 in Nebraska. Irrigation and cultivation should be discontinued at that time.

Seedling nutrition also is important. Kopitke (1941) found that a balanced supply of nutrients, and especially an adequate amount of potash, appeared to be the most important prerequisite for the production of frost-resistant stock. Maximum benefits were obtained when the concentration of potash was adequate to produce a vigorous seedling at the very beginning of development.

Pines and junipers in the Dakotas are likely to have a high percentage of their foliage browned by winter injury, even in second-year beds. Sometimes transplants are affected. The browning is due to loss of moisture from the needles while the ground is frozen and the roots are unable to supply moisture. This injury may occur in March or early April on bright, sunny days with high winds, low humidity, and air temperatures in the 41° to 60° F. range (Walker and Kerr 1954).

Mulches have been used extensively in conifer production in the Plains. Many different materials have been used, including snow fence, shade frames, rolled burlap, hay, and plastic sheeting.

A 2- or 3-inch layer of clean straw or marsh hay may be applied shortly before the soil freezes. Coverage should include the paths as well as the seedbeds and transplant beds. The mulch should be left on until March or April.

Sawdust is another mulch that has been tried. A layer 1¼ inches deep was effective in one experiment (Farnsworth et al. 1956.) Sawdust has been used extensively only in the Oklahoma nurseries, and there only as a thin covering over recently sown conifers, especially fall-seeded eastern redcedar.

Paper mulches have been tried experimentally, but do not appear to be competitive in cost with other materials (Robbins 1932).

Snow fence rolled out on the bedboards has given effective protection. Mulch may or may not be used under it.

All beds should be wetted for a few days before covering is applied.

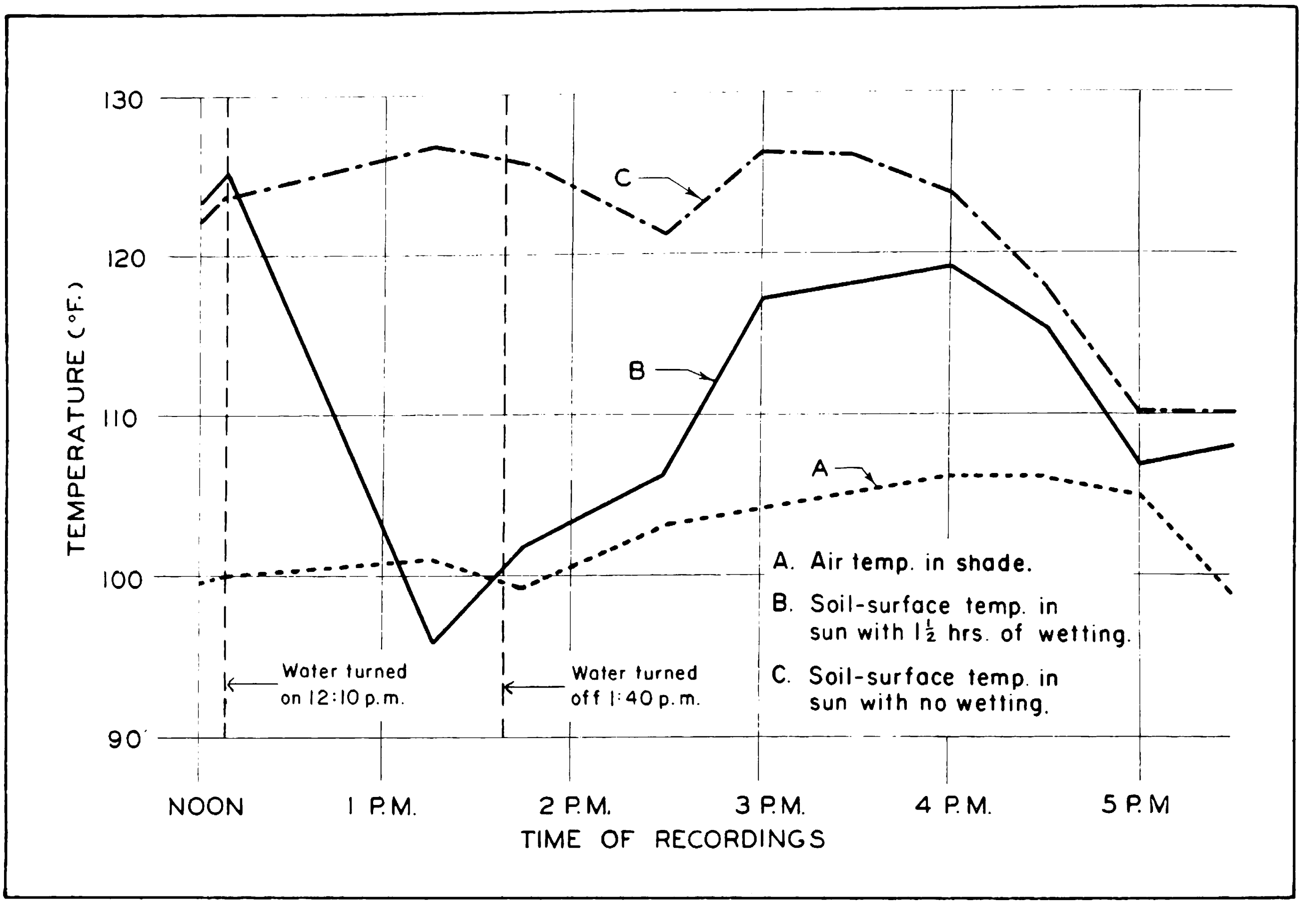

FIGURE 60.—Effect of watering on soil-surface temperatures: *A,* Air temperatures in shade; *B,* soil-surface temperatures in sun with 1½ hours of wetting; *C,* soil-surface temperatures in sun with no wetting. Towner Nursery, Towner, N. Dak.

As mentioned earlier, snow fences erected on every pipeline or on every second line aid in trapping snow within the nursery and afford some protection by keeping the trees covered with more snow and for a longer period in the spring. This practice is especially useful on transplant beds; however, it does not distribute the snow as uniformly as is desirable.

Frost heaving is a problem in northern nurseries. It occurs during open winters with little snow cover and in early spring when the seedlings are emerging. Often 1–0 stock is frost heaved partly or entirely out of the ground. Eastern redcedar and spruce are particularly susceptible. Removing the mulch at a date later than normal will reduce the damage from this source.

Fall-sown eastern redcedar seed germinates early in May in central Nebraska. When freezing temperatures may occur after germination, mulching with clean straw or marsh hay and sprinkling have been used to prevent frost.

Sometimes after overwinter mulches have been removed in the spring, a severe frost, with temperatures between 18° and 28° F., may be predicted. The trees may then be protected by rolling out snow fence on the bedboards or by rolling burlap directly on top of the half-shade or directly on top of 1-year-old frost-sensitive seedlings such as spruce or fir. Irrigation with an overhead sprinkler system also offers some protection. The sprinklers are turned on the beds of sensitive species as soon as, or slightly before, the temperature drops to 32° and are kept on until the temperature rises. In some instances a sheet of ice formed between the trees, but on melting, little or no damage had occurred from freezing (Stoeckeler and Jones 1957). Most of the effectiveness of this method in preventing frost damage is lost when the temperature reaches below 25°.

NURSERY INSECTS AND MITES

Insects and mites may cause serious damage in nurseries. Frequent checks are necessary to detect injuries in the early stages so that losses are reduced and control measures can be applied promptly. Damage may be to the roots or tops or both of seedling and transplant stock. Some insects, such as white grubs, are common nursery pests on both conifers and hardwoods in the Plains (Wygant 1936). Others, such as the Nantucket pine tip moth, attack only conifers and are found only in certain areas. The range of some insects is believed to have been increased through the distribution of infested nursery stock (Craighead 1950, Graham 1939).

Fortunately, in recent years an improved general knowledge of insects and their life cycles has made possible the efficient use of newly developed insecticides. The stomach insecticides are used for killing top feeders, especially larvae of moths, beetles, and sawflies. The arsenicals, particularly lead arsenate, are the most important inorganic stomach insecticides. Some organic insecticides, such as derris, pyrethrum, and tobacco products, are stomach poisons. The newer organic chemicals, such as DDT, chlordane, and benzene hexachloride, act as both stomach poisons and contact insecticides. Contact insecticides, which are used chiefly to control sucking insects, also include nicotine sulfate, pyrethrum, lime sulfur, sulfur dust, oils, and oil emulsions.

White Grubs

Larvae of the May beetle and related genera (*Phyllophaga spp.*) eat the roots of coniferous seedlings, causing death or reducing growth. Occasionally the tender stems of newly germinated seedlings are consumed.

The life cycle of the insect, 2 to 5 years, varies by species and latitude (Craighead 1950). For the more injurious species in South Dakota and Nebraska, it is 3 years. The adult beetles eat the foliage of deciduous trees, and the females oviposit in the soil near the trees. Most of the damage occurs during the second year of development, when the grubs are feeding heavily and larval growth is rapid. These larvae are white and have brown heads, stout, curved bodies, and six prominent legs.

At the Bessey Nursery in 1930, a grub population of one to eight per square foot caused losses of as much as 50 percent of transplant ponderosa pine, with some damage to jack and red pine. Losses have also occurred in 1–0 eastern redcedar beds. Severe damage to pine transplants reportedly occurred in a nursery in southeastern Manitoba (Prentice and Hildahl 1959).

Before seeding, white grub control can be obtained in nurseries through the application of 8 pounds of chlordane per acre. It is applied in the form of 80 pounds of 10-percent dust. The insecticide is mixed immediately with the soil to an 8-inch depth with a rotarytiller or disk (Speers and Schmiege 1961). A maintenance dosage of 1 to 1½ pounds per acre will be needed every 2 years. Dieldrin, applied at the rate of 1½ pounds per acre and then at one-half pound every 2 years, may be substituted for chlordane. Excellent control has been reported following fumigation with methyl bromide gas at the rate of 2 pounds per 100 square feet (Hill 1955).

Areas with trees receive an application of chlordane emulsion, applied at a dosage of 1 part in 200 parts of water, and then sprinkling for 3 to 4 hours to get the material into the soil. In western Kansas white grubs in potted evergreens also have been controlled by application of chlordane.[20]

Nantucket Pine Tip Moth

The Nantucket pine tip moth (*Rhyacionia frustrana* (Comst.)) is a pest of most species of two- and three-needled pines occurring throughout the East and through the Central States to Texas (Craighead 1950). A variety (*R. frustrana bushnelli* (Busck)) is more common in the Plains area of Minnesota, the Dakotas, and Nebraska. The larvae mine the shoots and buds of nursery stock and older trees. One or two larvae will hollow out only the buds or apex of the new shoot, but where they are numerous, the entire shoot may be riddled with their burrows, and deformation and stunting of the trees may result.

The larvae are yellow to pale brown and have brown heads. They are nearly one-half inch long when fully grown. Winter is passed in the pupal stage. The Nantucket pine tip moth pupates within the injured twig tip, and the form *bushnelli,* in the litter on the ground (Craighead 1950). One generation is produced each year in the Black Hills and in North Dakota, two occur in Nebraska (Wygant 1936), and up to four are produced in Oklahoma and Texas (Afanasiev and Fenton 1947, Craighead 1950).

The form *bushnelli* has long been a pest at the Bessey Nursery in Nebraska; infested seedlings were reported as early as 1911 (Swenk 1927). It was almost certainly introduced to this grassland area on infested stock (Graham and Baumhofer 1927). Ponderosa pine is most severely attacked, followed by red, jack, Scotch, and Austrian pines, in order of decreasing susceptibility.

In Oklahoma the native shortleaf and loblolly pines are heavily infested. Also attacked are Japanese red, Austrian, Scotch, Japanese black, and ponderosa pines, in descending order of their attractiveness to *bushnelli.* The larvae are thought to prefer those species with thin, soft, flexible needles (Afanasiev and Ashdown 1951).

The danger of introducing the pine tip moth into nurseries and plantings on infested stock cannot be overemphasized. For control of the Nantucket pine tip moth on planting stock, Hall (1936) recommends that all seedbeds and transplants be checked in the fall for evidence of the insect and that all infested tips or buds be removed and destroyed. Fumigation of stock moving into or out of the nursery will kill eggs, larvae, and pupae. A commonly used control measure is to dip infested stock before shipment in a miscible oil, alone or mixed with nicotine.

[20] Personal communication with Melvin Dimitt, Nurseryman, Garden City, Kans.

Beds where the insect is present should be sprayed with DDT.

Red Spiders

Various species of red spiders attack evergreens growing on the Plains. Nursery stock may become infested if it is grown close to trees with mite populations. Red spiders are acarinids and not insects but are considered here because control measures for these pests are similar to those used against certain insects. Although small, their number increases rapidly, particularly when the weather is hot and dry. They suck the juices of plants, causing premature yellowing and falling of the foliage.

The adults hibernate in the soil or in other protected places and begin laying their eggs in early summer. Several generations develop during the summer. Their irregular webs spun over the leaves and stems of plants help protect the spiders from wind and rain but also signal their presence.

The two-spotted spider mite *Tetranychus telarius* (L.) is the most common and injurious species (Craighead 1950); it has attacked juniper, spruce, and pine in Plains nurseries. It was particularly troublesome on juniper species at the Bessey Nursery prior to the removal of eastern redcedar windbreaks in 1958. Ponderosa pine seedlings and transplants are also attacked in this nursery.

The spruce spider mite *Oligonychus ununguis* (Jacobi) is a pest of ornamental evergreens and coniferous forest trees and has been reported from North Dakota (Goodfellow and Colberg 1958) and on the Canadian prairie (DeGryse 1924). Favorite hosts include *Picea, Juniperus,* and *Cupressus* (Pritchard and Baker 1955). Nonphosphate acaricides, including aramite, Dimite, chlorobenzilate,[21] and others, have proven highly effective in controlling infestations. These materials have the advantage of not being harmful to insects, and the various species of spider mites apparently have not acquired immunity to them (Johnson 1958).

The materials are mixed with water and applied at the recommended dosages from the ground by garden-type or commercial spraying equipment. The foliage should be wetted thoroughly, and applications should be repeated when injury is evident or increasing.

Wireworms

Wireworms are long, cylindrical, brown, hard-shelled "worms," usually with well-developed legs, that feed in the soil on small roots and other plant materials. They are the larvae of the click beetles (Elateridae). Most species are crop feeders. The roots of newly germinated seedlings of eastern redcedar have been attacked at the Bessey Nursery, but damage was slight, as new roots developed.

[21] To avoid using technical names, common names are given as listed by the Committee on Insecticide Terminology of the Entomological Society of America for use in the Journal of Economic Entomology. (Haller, H. L., 1957. Common names of insecticides. Jour. Econ. Ent. 50: 226–228).

Plowing, harrowing, disking, and cultivation used in the nursery for various purposes tend to reduce populations. Use of soil fumigants such as ethylene dibromide has given good control of wireworms (Keen 1952).

Cutworms

Cutworms appear occasionally on conifers in Plains nurseries; they damage the young trees considerably by feeding on the foliage, tender roots, or stems, and by clipping off seedlings at the ground line (Craighead 1950). They are the larvae of night-flying moths of the family Phalaenidae, commonly referred to as millers. They have been reported in 1–0 seedbeds of the Monument Nursery in Colorado[22] and the Savenac Nursery in Montana.[23] Slight damage has been reported at the Bessey Nursery.[24]

Control can be obtained by spreading commercially prepared baits over the beds in the late afternoon. Dusts of DDT or chlordane also are effective.

Grasshoppers

Grasshoppers are primarily pests of agricultural crops, but they may strip the foliage from conifer nursery stock, particularly during outbreaks and drought years. Grasshoppers can be controlled with sprays, dusts, or baits.

Sprays may be composed of one of the following active ingredients, in the following amounts per acre: Aldrin, 1½ to 2 ounces; chlordane, one-half to 1 pound; or Toxaphene, 1 to 1½ pounds (Parker and Cowan 1953). The lower dosages are used on young grasshoppers or in areas where the vegetation is short or sparse. A buffer strip 100 yards wide outside the nursery as well as the nursery stock should be treated. Treatment is started when the young grasshoppers begin to move from their places of hatching.

Other chemicals used in grasshopper control are methoxychlor, Dieldrin, parathion, and dilan, but these should not be used unless specifically recommended by county agents or the State entomologist.

In 1928, in the coniferous plantations adjacent to the Bessey Nursery, grasshopper damage was heaviest on Scotch and Austrian pine foliage and stems; in jack and ponderosa pine, the stems were preferred to the foliage; ponderosa pines seldom were chewed.[25] No damage to the junipers was reported.

[22] U.S. Forest Service. 1931 Annual Planting Report, Region 2, Denver, Colo.

[23] U.S. Forest Service. 1937 Annual Nursery Report, Savenac Nursery, Region 1, Missoula, Mont.

[24] U.S. Forest Service. 1937 and 1951 Fiscal Year Annual Nursery Reports, Bessey Nursery, Region 2, Denver, Colo.

[25] U.S. Forest Service. Calendar Year 1928 Annual Planting Report, Nebraska National Forest, Region 2, Denver, Colo.

In 1949, grasshoppers were in the Bessey Nursery, but they confined their eating mainly to the green manure crops.[26]

NURSERY DISEASES

Disease control, according to Hartley (1935a), is largely a matter of prevention by proper selection of nursery sites and species and by attention to soil condition, stand density, and sanitation. However, even if all reasonable precautions are taken, some diseases are almost certain to be a problem at some time in every nursery.

Damping-off

Damping-off is a generalized term applied to the killing by fungi of very young seedlings just before or after they emerge from the ground. It is common throughout Plains nurseries and is the strongest deterrent to the growing of conifers other than the junipers from seed in this region. Losses from this cause are sporadic and are slight to complete. Often this situation introduces great uncertainty into nursery operations by upsetting stock production schedules, influencing stand densities, and causing wastage of seed.

Damping-off affects the seedlings of most conifers; only the genera *Juniperus, Cupressus, Thuja,* and *Chamaecyparis* are resistant to it (Hartley 1921). Heavy losses to pine and spruce beds have occurred in the Canadian prairie provinces, the Dakotas, and elsewhere. In 1933, at the Bessey Nursery in Nebraska, ponderosa pine suffered postemergent losses up to 50 percent, and the red pine was almost completely destroyed.[27]

Hartley (1935a) identified various species of the genera *Pythium, Rhizoctonia,* and *Fusarium* as causal organisms of damping-off. Pathogenic tests on seeds of white spruce, blue spruce, Scotch pine, and caragana at Indian Head, Saskatchewan, showed the same genera but indicated that *Rhizoctonia* was the most virulent isolate (Cram 1956b). Thomas (1953), in a preliminary report, suggests that *Pythium* isolates were the main cause of damping-off losses in conifers in Saskatchewan.

To minimize damping-off losses, seedbeds should be located on sandy soils with good internal drainage. Heavy or excessively wet soils should be avoided.

Damping-off is increased in severity by the use of poorly rotted manures, dried blood, or materials that increase the carbon-nitrogen ratio of the soil (Hartley 1935b). Incorporation of certain cover or soil improvement crops into the soil prior to seeding may have the same effect. In general, legumes, especially sweetclover and redclover, increase damping-off. In central Illinois, 64 percent fewer red pine seedlings were produced in seedbeds where a green manure crop of cowpeas or soybeans with Sudangrass had been plowed under while green than in seedbeds with no cover crop (Wycoff 1952). Fumigating the soil or removing the crop (instead of plowing it under) are suggested methods of reducing losses from damping-off where new seedings follow these crops by necessity at an interval of less than 4 to 6 weeks. The possibility of damping-off is also increased by the addition of other materials that decrease acidity, such as lime, limy sand, wood ashes, or nitrates, and the use of irrigation water that has a hardness of over 100 p.p.m. as $CaCO_3$ or 125 p.p.m. as a bicarbonate (Davis et al. 1942). Damping-off fungi may be introduced in infected nursery stock from distant nurseries or in soil brought into the nursery on machinery.

There are three principal methods of controlling or reducing the incidence of damping-off. They are soil acidification, soil sterilization or fumigation, and the application of fungicides to the seed or soil.

In Plains nurseries, soil acidification is commonly used since it has the added advantage of counteracting the tendency toward soil alkalinity where alkaline waters are applied in irrigation. The amount of acidifying material to apply depends largely on soil texture and its pH before treatment, but it usually consists of one-sixteenth to one-eighth fluid ounce of concentrated sulfuric acid per square foot. The acid is diluted in water to a 2-percent solution by volume. It is applied immediately after the seed is sown, and the beds are then watered. Sulfuric acid has been most effective in damping-off control of the acidifying materials tested, including sulfur.

Other materials, such as aluminum sulfate, ferrous sulfate, and phosphoric acid, are also useful for controlling pre-emergence and ordinary damping-off loss. At the Bessey Nursery, aluminum sulfate cost less than ferrous sulfate and produced superior results. Here, postemergence applications of one-half ounce of aluminum sulfate in water per square foot has successfully curbed early summer damping-off. Good control has been obtained with an annual application of 15 grams of aluminum sulfate per square food of seedbed; it is broadcasted dry and watered in.[28]

Deep treatment with one-fourth to one-half avoirdupois ounce of sulfur per square foot, mixed into the soil to a depth of 6 or 8 inches, has value as a damping-off control and will lower the pH of the soil for a longer time than other acidification treatments (Stoeckeler and Arneman 1960). To avoid acid injury, the sulfur should be well pulverized and applied for several warm months or a full year before seeding.

Fumigating nursery seedbeds with gaseous methyl bromide reduces damping-off losses. Side benefits in-

[26] U.S. Forest Service. Fiscal Year 1950 Annual Nursery Report, Bessey Nursery, Region 2, Denver, Colo.

[27] U.S. Forest Service. Calendar Year 1933 Annual Nursery Report, Bessey Nursery, Region 2, Denver, Colo.

[28] Personal communication with E. W. Johnson, Agricultural Research Service Field Station, Woodward, Okla.

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clude the control of weeds, nematodes, insects, and other soil-borne plant parasites. Standard dosages for damping-off control are 1 to 2 pounds per 100 square feet of soil surface. A machine used at the Chittenden Nursery, Wellston, Mich., applies the vaporized fumigant rapidly under a polyethylene cover laid directly over the seedbed (Clifford 1959). Cockerill (1957), testing methyl bromide in Ontario, found that it reduced pre-emergence losses and resulted in higher emergence of seedlings, but failed to control later damping-off.

Another means of soil sterilization is the use of one-fourth fluid ounce of commercial 40–percent formaldehyde per pint of water per square foot of seedbed. This solution is applied 7 to 10 days before seeding, and the soil is then heavily watered (Davis *et al.* 1942). Seven days is sufficient in warm weather or on soils with abundant humus, while 10 days is necessary in cold, damp weather or on heavier soils.

Pelletizing seed with a fungicide has given better protection than seed dusts. Furthermore, bird and animal repellents can be incorporated in the pelletizing material, and a larger and more uniform seed is produced for sowing. Mony (1958) reported control of early damping-off at the Vallonia Nursery, Vallonia, Ind. He used a fungicide-insecticide pelletized mixture consisting of equal parts of 75–percent thiram, 50–percent captan, and 50–percent W. endrin. He discusses equipment, materials, and methods used in pelletizing.

In Southern nurseries, seed treatments with fungicidal dusts have given virtually no control of damping-off of southern pines or other pines (Wakeley 1954).

Soil dusts applied before seeding show promise of providing more prolonged protection than that secured with seed dusts. Tests of several soil dusts (Strong 1952) indicated that the following were the most promising in Michigan: Thiram (wettable tetramethyl thiuram disulfide), experimental fungicide 5400, 31 parts of Ceresan M (ethyl mercury p-toluane sulfonanilide) plus 1 part of potassium iodide, and maneb (manganese ethylene bisdithiocarbamate). These fungicides were mixed with soil and applied dry with commercial fertilizers at the rate of 150 pounds of fungicide per acre. The beds were then rototilled to a depth of 5 inches. Treatment should be made 3 days before seeding; if rain occurs, seeding should be postponed for 6 days.

In Saskatchewan, soil drenches with Thiram (75 percent) or captan (75 percent) gave very good control of *Rhizoctonia solani* without damage to seedlings in a test on blue spruce, Scotch pine, and caragana (Cram and Vaartaja 1957). The first application, made prior to seeding, was fairly heavy (0.6 gram thiram per square foot); later, postemergent light applications were made at 1- or 2-week intervals (0.1 gram). These materials are particularly useful since they can be used to control postemergent damping-off in seedbeds where preseeding control measures have been neglected or proven inadequate.

Indirect methods of controlling damping-off include sowing at lower seedbed densities, covering the seed with clean nonalkaline sand, and removing half-shade or seedbed covers during prolonged damp weather.

Cedar Blight

Cedar blight is the most damaging disease affecting junipers. It occurs wherever eastern redcedar is produced and has caused heavy losses in Plains nurseries from North Dakota to Texas. The causal organism, *Phomopsis juniperovora,* invades the leaves and small stems, particularly those of the new growth. The foliage turns brown and the stem dries out (Baxter 1952). The tips die back and usually the small trees die. Spores are produced from small, dark fruiting bodies or pycnidia in the stems and needles of the infected trees. Under moist or humid conditions, *Phomopsis* spores are readily disseminated and infect other plants (Davis et al. 1942). Seedlings and transplants are subject to attack throughout the growing season.

A number of nurseries have been contaminated by the introduction of blighted cedar as transplants. There is a little evidence that contamination is possible by spore dissemination from nearby infected plantings. The blight in native redcedar in eastern Nebraska was considered the source of infection in a nearby nursery (Davis and Latham 1939). Once the disease has been introduced into a nursery, it is practically impossible to eradicate, and a continuing program of control is required as long as junipers are produced. Blight-free redcedar was produced at the Bessey Nursery for more than 40 years before the blight appeared in 1956, supposedly from infected planting stock.

Eastern redcedar, Rocky Mountain juniper, and their horticultural varieties are particularly susceptible, but other junipers and Arizona cypress are also attacked. Rocky Mountain juniper has been damaged less than eastern redcedar, probably because of its slower growth. At Manhattan, Kans., losses of eastern redcedar during a 3-year period averaged five times greater than those of Rocky Mountain juniper.[29] In the Prairie States Forestry Project Nursery at Fremont, Nebr., Rocky Mountain juniper was much more resistant to blight than eastern redcedar.[30]

Caroselli (1957) reported that WK–34 gave good control of *Phomopsis* blight when applied at 2- to 3-week intervals to 1- or 2-year-old seedlings at the rate of 1.2 ounces per 10 gallons of water. This spray contained 12 p.p.m. of cycloheximide (an antibiotic) and 675 p.p.m. of pentachloronitro benzene.

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[29] Slagg, C. M., and Wright, Ernest. *Phomopsis* blight of eastern redcedar and its control. 1943. Unpublished report on file at the Lincoln Field Station, Lincoln, Nebr., Rocky Mountain Forest and Range Expt. Sta., U.S. Forest Serv., Fort Collins, Colo.

[30] Personal communication with S. S. Burton, formerly Woodland Conservationist, Soil Conservation Service, Lincoln, Nebr.

Excellent control has also been obtained by the use of Puratized Agricultural spray (phenyl mercury compound) at the Oklahoma State Nursery at Norman. Sprays were applied at weekly intervals or more frequently if needed.

Spraying should be part of the regular nursery operation and should include all seedlings and transplants. Sprays should be applied every 7 to 10 days throughout the growing season. Twice-weekly applications may be necessary during moist, cool weather (Hodges 1962).

Rusts

Native rust-induced galls are widely distributed on two- and three-needled pines and to a lesser extent on junipers. The rusts considered here include only those fungi that develop on living leaves, stems, or branches without immediately killing them. Infected planting stock, however, may die after field planting.

The western gall rust, *Peridermium harknessii*, occurs in the West and has been observed in Prairie-Plains nurseries (Boyce 1961, Davis et al. 1942). Ponderosa and lodgepole pines are particularly susceptible. A ball-shaped gall is formed on the stem. The aeciospores can cause pine-to-pine infection (Meinecke 1929); hence, control cannot be effected by eliminating the alternate hosts, which may be paintbrush, lousewort, owlclover, or birdbeak. Infected stock should be eliminated by grading.

The southern fusiform rust is caused by *Cronartium fusiforme*. Limited to the Southern States, it attacks a number of hard pines, including shortleaf and loblolly. Infected seedlings have spindle-shaped stem swellings. Control requires weekly spraying with ferbam, ziram, or zineb prior to infection (Foster 1959). All seedling tissue must be completely covered.

The eastern gall rust (*Cronartium cerebrum*) ranges eastward from the Prairie-Plains and is most abundant in the Southen States (Boyce 1961). Jack pine and shortleaf pine are favorite hosts. Oak is the alternate host. Control measures are similar to those recommended for the southern fusiform rust.

Large transplants or large ornamental stock of eastern redcedar, Rocky Mountain juniper, and other junipers are subject to cedar-apple rust (*Gymnosporangium juniperi-virginianae*). Round galls, 1 or more inches in diameter, are produced, but damage to the susceptible conifers is usually light. Control is obtained by spraying the junipers with a general purpose fruit spray containing ferbam or zineb fungicides at the rate of 1 to 1½ level tablespoons of wettable powder per gallon of water. These fungicides should be applied at 7- to 10-day intervals from late July to early September. Another effective spray is Elgetol, formulated at the rate of 1 gallon per 100 gallons of water and applied when the telial horns are small.

Antibiotics show great promise for providing effective control of rust diseases in nurseries, but detailed application methods are still to be developed.

Nematodes

Nematodes are tiny, threadlike, soil-inhabiting roundworms that feed on the roots of trees, especially small seedlings. They weaken the trees and may also provide entry courts for root rot fungi. The typical symptoms of nematode injury (Hodges 1962) are a general decline, stunting, and chlorosis of the seedlings. The control of nematodes in nurseries is a necessity in many areas of the country. Their control in Prairie-Plains nurseries will assume greater importance when the damage they cause is recognized and diagnosed correctly.

The root-lesion nematode has been recovered from the roots of eastern redcedar at Halsey, Nebr. (Caveness 1957), but not from those of ponderosa or Austrian pine. Stock of 1–0 and 1–1 age class was affected. After the roots of the 1–0 stock were infected at varying depths, the plants showed slightly offcolor foliage and reduced growth, and some mortality resulted.

The nematodes may be eliminated by treating the soil with methyl bromide gas at the rate of 1½ to 2 pounds per 100 square feet, ethylene dibromide at 3 to 6 gallons (85 percent EDB) per acre, or chloropicrin at 3 to 5 cubic centimeters per cubic foot of soil (Munnecke 1957). At the Bessey Nursery use of 1 pound of methyl bromide gas per 100 square feet gave good control of the root-lesion nematode.[31]

The manufacturer's directions on the method of treatment should be followed.

Dieback

Pine twig blight is a dieback of the current season's growth of hard pines caused by the fungus *Diplodia pinea* (Desm.) Kickx. Severe damage to seedlings of Austrian pine has been reported from a Kansas nursery by Slagg and Wright (1942). They also reported (1943) considerable damage from this blight in Southern Plains nurseries on Austrian and ponderosa pines, pinyon, and Douglas-fir.

Root Rots

The *Phymatotrichum* root rot has not been reported from nurseries, but it may become a problem there since it occurs in Oklahoma, Texas, and other parts of the Southwest where shelterbelt plantings are important. Both conifers and hardwoods are attacked, but eastern redcedar and Rocky Mountain juniper have a high resistance to the disease (Wright and Wells 1948). Based on 6 years of fieldplanting tests in Oklahoma and Texas, ponderosa and loblolly pines were susceptible and not recommended for use, while Austrian pine was less susceptible and considered capable of surviving on the more sandy soils.

[31] Personal communication with Glenn Peterson, Rocky Mountain Forest and Range Experiment Station, Lincoln, Nebr.

MAMMALS AND BIRDS

Practically all nurseries are situated so that a fence is necessary to exclude domestic livestock or the larger wild animals such as deer. Some nurseries use woven wire fence or slat-wire snow fence, which will also exclude dogs or even rabbits. The intensity of protection used will depend entirely on the local situation.

If deer are a problem, a fence at least 10 feet high is necessary. At the Bessey Nursery extensive damage to seedlings by deer necessitated fencing and later live trapping when ordinary cattle guards failed to exclude deer at road entrances. In 1945, an estimated one million jack, Scotch, and Austrian pine seedlings were nipped and trampled by deer. The preferred species was eastern redcedar, followed by jack pine. Rocky Mountain juniper and Austrian pine were browsed to a lesser extent. Winter cover crops feed the deer in years of low animal population but attract additional animals to the nursery.

Jackrabbits, cottontail rabbits, and snowshoe hares may damage Plains nurseries. It is difficult to maintain a fence high and tight enough to exclude rabbits because they may come in over snowdrifts or get through under the wire. Occasional checking is necessary to determine whether rabbits have gained entrance and are doing damage by cutting off the tips of the seedlings. Cover crops may be eaten in preference to trees. If present, rabbits can be eliminated by snaring, trapping, or shooting.

Pocket gophers (*Geomys* and *Thomomys*) occasionally cut tree roots and smother seedlings under mounds in nurseries. They live almost exclusively in the ground, pushing out the soil to form troublesome mounds as they excavate their tunnels 4 to 8 inches below the surface. Effective controls include the use of regular pocket gopher traps or the placement of poisoned bait in the runways. Two or three pieces of diced fresh carrots or similar vegetable, dusted with strychnine alkaloid, at the rate of one-fourth ounce of powder to 4 quarts of carrots, should be put in several places in each burrow system. In replugging the placement holes, care should be taken to avoid covering the bait. Pocket gopher control should extend nearly one-fourth mile beyond the nursery since migration is sometimes extensive.

Many species of white-footed mice (*Peromyscus* spp.) may eat the seed of conifers as well as that of hardwoods. The meadow mouse (*Microtus*) eats seeds, and the pine vole (*Pitymys*), in an area from eastern Kansas south, may cut off small seedlings. Kangaroo rats (*Dipodomys*) have eaten pine seed in Nebraska nurseries.

Straw mulches used on seedbeds over the winter are especially attractive to mice and other rodents. Populations can be kept down by eliminating weeds and grass in fence rows. Hardware-cloth screens placed on bedboards also are used to protect the beds. Mice can be trapped easily with ordinary snap traps that are baited with peanut butter, an apple, a vegetable, or oatmeal, and placed in runways or near entrances of burrows.

The use of poisoned baits is probably the cheapest and most effective way of eliminating mice and some of the other seed-eating rodents, such as ground squirrels.

The principal poisons used are strychnine alkaloid and zinc phosphide. Poisoned grain may be mixed with mulch as it is applied to fall-sown beds, or it may be placed at bait stations at 100-foot intervals. The stations are staggered somewhat where bedboards tend to confine and channelize rodent movement. Outside the nursery, bait should be placed along the fence and in a bordering zone extending about 200 feet from the fence. In this zone, especially if it is grassy, bait should be spaced as close as 30 feet apart, in four lines paralleling the fence at intervals of about 50 feet. Commonly the bait is placed in small tin cans laid on their sides. Thus protected, the bait will remain effective for a longer time, and birds cannot reach it. *Do not place bait where livestock will have access to it.*

Moles damage new seedlings and 1–0 seedbeds by loosening the ground with their slightly raised runways. The runways also expose the seed or bury it too deeply. Moles may cut tree roots in a manner similar to that used by pocket gophers. These animals must be removed from the seedbeds as well as a small surrounding area. Mole traps and poison baits are effective.

Nurserymen with rodent problems may wish to write to the Fish and Wildlife Service, U.S. Department of the Interior, Washington, D.C., for the address of the nearest poison-bait distribution center. Prepared baits are available at such centers at cost. An alternative to the purchase of prepared baits is to use one of several formulas recommended by the Fish and Wildlife Service (Garlough and Spencer 1944) and to prepare the bait at the nursery. Two poison-bait formulas for mice are given in the Appendix on page 89.

Seed-eating birds may be a serious problem in conifer nurseries, particularly in years when the peak of the spring migration coincides with seedling emergence. They not only scratch out the seed and eat it, but also they nip the tops of the seedlings after they have emerged from the soil but still retain the seedcoats. A more localized form of damage is debudding of Austrian pine seedlings by sharp-tailed grouse (*Pedioecetes phasianellus*) during the winter.

Birds can be excluded by hardware-cloth screens placed over all seedbeds or those of the most susceptible species (fig. 61). At the Bessey Nursery fall-sown beds of juniper and Austrian pine are screened. More birds take the smaller seed of Austrian pine than that of ponderosa pine. Fall-sown juniper beds are damaged in early spring by the white-crowned sparrow (*Zonotrichia leucophrys*).

Repellents such as sublimated anthroquinone are being applied to seed in Southern nurseries (Mann and

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FIGURE 61.—Pettis screen section for seedbed protection from birds and rodents at Bessey Nursery, Halsey, Nebr. Each section is 4½ by 10 feet; ½-inch-mesh netting is used.

Kingsley 1958) and elsewhere (Abbott 1958) to protect seed before and during germination. Anthroquinone with a latex sticker should be applied at the rate of 15 pounds to 100 pounds of seed. Arasan, another bird repellent being used in Plains nurseries, also has rodent repellent qualities.

Another method of reducing bird damage is to vary the time of seed sowing. Fall sowing results in earlier germination, and in some localities the seedling emergence is completed by the time the main flight of certain species of migratory birds arrives. In other instances, spring sowing may be delayed until the main offenders have passed on their way north.

Some degree of control may be secured by systematic patrolling of the seedbeds in daylight during the critical germination period.

Shooting of the birds should be limited strictly to those species not protected by State or Federal law.

LITERATURE CITED

AAMODT, E. E.
1941. Stem caliper gauge for nurseries. Jour. Forestry 39: 728, illus.

ABBOTT, HERSCHEL G.
1958. Application of avian repellents to eastern white pine seed. Jour. Wildlife Mangt. 22: 304–306.

AFANASIEV, M.
1949a. Cedar and pine as farm trees for Oklahoma. Okla. Agri. Expt. Sta. Bul. B–331, 18 pp., illus.

———
1949b. Observations on Japanese red pine and black pine in central Oklahoma. Jour. Forestry 47: 723–725, illus.

———
1955. Storage of afterripened seed of eastern redcedar. U.S. Forest Serv. Tree Planters' Notes 21: 28–30.

——— AND ASHDOWN, D.
1951. The pine tip moth. Okla. Agr. Expt. Sta. Bul. B–377, 11 pp., illus.

——— AND CRESS, M.
1942a. Producing seedlings of eastern redcedar (*Juniperus virginiana* L.). Okla. Agr. Expt. Sta. Bul. B–256, 21 pp., illus.

——— AND CRESS, M.
1942b. Changes within seeds of *Juniperus scopulorum* during process of afterripening and germination. Jour. Forestry 40: 793–801.

——— ENGSTROM, ALBERT, AND JOHNSON, ERNEST W.
1959. Effects of planting dates and storage on survival of eastern redcedar in central and western Oklahoma. Okla. Agr. Expt. Sta. Bul. B–527, 19 pp., illus.

——— AND FENTON, F. A.
1947. Pine tip moth and its control in Oklahoma. Jour. Forestry 45: 127–128.

ALBERTSON, F. W.
1940. Studies of native redcedars in west central Kansas. Kans. Acad. Sci. Trans. 43: 85–95, illus.

ALLAWAY, W. H.
1957. pH, soil acidity, and plant growth. U.S. Dept. Agr. Yearbook 1957: 67–71.

ALLEN, G. S.
1957. Storage behavior of conifer seeds in sealed containers held at 0° F., 32° F., and room temperature. Jour. Forestry 55: 278–281.

ALLEN, R. M.
1952. Ferbam controls nursery weeds. U.S. Forest Serv. Tree Planters' Notes 12: 8.

ALLISON, F. E., AND ANDERSON, M. S.
1951. The use of sawdust for mulches and soil improvement. U.S. Dept. Agr. Cir. 891, 19 pp.

ANDERSON, C. H., AND CHEYNEY, E. G.
1934. Root development in seedlings in relation to soil texture. Jour. Forestry 32: 32–34, illus.

ANDERSON, D. A., AND KINEER, G. U.
1949. The use of copper naphthenate treated burlap in forest nursery operations. Jour. Forestry 47: 470–473.

ARNOLD, INGERSOLL.
1956. Drill vs. broadcast sowing. U.S. Forest Serv. Tree Planters' Notes 26: 5–6.

BAKER, F. S.
1929. Effect of excessively high temperatures on coniferous reproduction. Jour. Forestry 27: 949–975.

BAKER, KENNETH F., CHANDLER, PHILLIP A., DURBIN, RICHARD D., AND OTHERS.
1957. The U. C. system for producing healthy container-grown plants. Univ. Calif. Agr. Expt. Sta. Ext. Serv. Manual 23, 332 pp., illus.

BARTON, H. ALLEN.
1940. Grading gauge for tree seedlings. U.S. Forest Serv. Planting Quart. 9(1): 14.

BARTON, L. V.
1935. Storage of some coniferous seeds. Boyce Thompson Inst. Contrib. 7: 379–404, illus.

———
1951. Germination of seeds of *Juniperus virginiana*. Boyce Thompson Inst. Contrib. 16: 387–393.

———
1954. Effect of subfreezing temperatures on viability of conifer seeds in storage. Boyce Thompson Inst. Contrib. 18: 21–24.

BATES, C. G.
1910. Experiments in sandhill planting. Soc. Amer. Foresters Proc. 5: 59–83.

——— 1927. A vision of the future Nebraska forest. Jour. Forestry 25: 1030–1040.

——— 1935. Climatic characteristics of the Plains regions. *In* Possibilities of shelterbelt planting in the Plains region. U.S. Forest Serv. Spec. Pub., pp. 83–110, illus.

——— AND ROESER, JACOB, JR.
1924. Relative resistance of tree seedlings to excessive heat. U.S. Dept. Agr. Bul. 1263, 16 pp., illus.

BAXTER, DOW VAWTER.
1952. Pathology in forest practice. Ed. 2, 601 pp., illus. New York.

BERGEMANN, J.
1956. Das mykorrhiza Problem in der Forstwirtschaft (The mycorrhiza problem in forestry). Allgemeine Forstzeitschr. 11: 297–304.

BESSEY, CHARLES E.
1895. Notes on the distribution of the yellow pine in Nebraska. Garden and Forest 8: 102–103, illus.

BJÖRKMAN, ERIK.
1953. Om "granens gulspelssjuka". Svenska Skogsvfören. Tidskr. 51: 211–229.

BOE, KENNETH N.
1954. Periodicity of cone crops for five Montana conifers. Mont. Acad. Sci. Proc. 14: 5–9.

BOUYOUCOS, GEORGE JOHN.
1937. Evaporating the water with burning alcohol as a rapid means of determining moisture content of soils. Soil Sci. 44: 377–383, illus.

——— 1956. Improved soil moisture meter. Agr. Engin. 37: 261–262.

BOYCE, JOHN SHAW.
1961. Forest pathology. Ed. 3, 572 pp., illus. New York.

BRAY, W. L.
1904. Forest resources of Texas. U.S. Bur. Forestry Bul. 47, 71 pp., illus.

BREWSTER, DONALD W., AND LARSEN, J. A.
1925. Studies in western yellow pine practice. Jour Agr. Res. 31: 1101–1120.

BRIGGS, A. H.
1939. Report of planting experiments to determine the effect of root exposure on deciduous planting stock. Jour. Forestry 37: 939–943.

BRISCOE, CHARLES G., AND STRICHLAND, FREDDIE R.
1956. Vapam shows promise as a forest nursery herbicide. U.S. Forest Serv. Tree Planters' Notes 26: 3–4.

BROWN, GEORGE K.
1937. Results in survival following cold storage of planting stock. U.S. Forest Serv. Planting Quart. 6: 21–24.

BULL, W. IRA.
1954. Machine for applying sand or sawdust to seedbeds. U.S. Forest Serv. Tree Planters' Notes 18: 20–21, illus.

BÜSSE, J.
1930. Forstlexikon. Vol. 2, 423 pp. Berlin: Paul Parey.

CALLAHAM, R. J., AND METCALF, WOODBRIDGE.
1959. Altitudinal races of *Pinus ponderosa* confirmed. Jour. Forestry 57: 500–502.

CAROSELLI, N. E.
1957. Juniper blight and progress on its control. U.S. Agr. Res. Serv. Plant. Dis. Rptr. 41: 216.

CAVENESS, F. E.
1957. Root lesion nematode recovered from eastern redcedar at Halsey, Nebraska. U.S. Agr. Res. Serv. Plant Dis. Rptr. 41: 1058.

CHADWICK, L. C.
1938. Green manure crops and fertilization for nursery stock. Ohio State Univ. Nursery Notes 7: 1–11.

CHAPMAN, A. G.
1936. Scarification of black locust seed to increase and hasten germination. Jour. Forestry 34: 66–74, illus.

CHILEAN NITRATE EDUCATIONAL BUREAU, INC.
1948. Bibliography of the literature on the minor elements and their relation to plant and animal nutrition. Chilean Nitrate Ed. Bur. Inc. Pub. 1: 1037 pp.

CLIFFORD, E. D.
1934. Quack grass and white grubs. U.S. Forest Serv. Planting Quart. 3 (3): 9–10.

——— 1952. Use of 2,4-D to control weeds in conifer nurseries. U.S. Forest Serv. Tree Planters' Notes 12: 6.

——— 1955. The use of sawdust as a mulch on red, white, and jack pine seedbeds. U.S. Forest Serv. Tree Planters' Notes 21: 24–25.

——— 1956a. Seedbed root pruner. U.S. Forest Serv. Tree Planters' Notes 24: 11–12.

——— 1956b. Use of a potato digger for lifting nursery stock. U.S. Forest Serv. Tree Planters' Notes 24: 9–10.

——— 1959. A rapid method of fumigating nursery soils with methyl bromide. U.S. Forest Serv. Tree Planters' Notes 37: 9–10, illus.

COCKERILL, J.
1957. Experiments in the control of damping-off of the nursery, Orono, Ontario. Forest. Chron. 33: 201–204.

COCKERILL, P. W., HUNTER, B., AND PINGREY, H. B.
1939. Type of farming and ranching areas in New Mexico. N. Mex. Agr. Expt. Sta. Bul. 261, 68 pp., illus.

COLBRY, VERA L., SWOFFORD, THOMAS F., AND MOORE, ROBERT P.
1961. Tests for germination in the laboratory. U.S. Dept. Agr. Yearbook 1961: 433–443.

COLMAN, E. A.
1947. Manual of instruction for use of the fiberglass soil moisture instrument. U.S. Forest Serv. Calif. Forest and Range Expt. Sta. (Berkeley). (Rev. 1950.)

CORSON, C. W.
1935. The Susanville Nursery transplant plow. U.S. Forest Serv. Planting Quart. 4 (2): 6.

COSSITT, F. M.
1937. The W. W. Ashe nursery seedling lifter. U.S. Forest Serv. Planting Quart. 6: 11.

CRAIGHEAD, F. C.
1950. Insect enemies of eastern forests. U.S. Dept. Agr. Misc. Pub. 657, 679 pp., illus.

CRAM, W. H.
1951. Spruce seed viability: dormancy of seed from four species of spruce. Forest. Chron. 27: 349–357.

——— 1956a. Maturity of Colorado spruce cones. Forest Sci. 2: 26–30.

——— 1956b. Fungicidal control of *Rhizoctonia* damping-off. U.S. Forest Serv. Tree Planters' Notes 24: 17–18.

——— 1957. Maturity of white spruce cones and seed. Forest Sci. 3: 263–269.

——— AND BRACK, C. G. E.
1953. Performance of Scotch pine races under prairie conditions. Forest. Chron. 29: 334–342.

——— AND VAARTAJA, O.
1957. Rate and timing of fungicidal soil treatments. Phytopath. 47: 169–173.

CUMMINGS, W. H.
1942. Exposure of roots of shortleaf pine. Jour. Forestry 40: 490–492.

CURTIS, JAMES D., AND LYNCH, DONALD W.
1957. Silvics of ponderosa pine. U.S. Forest Serv. Intermountain Forest and Range Expt. Sta. Misc. Pub. 12, 37 pp., illus. (Ogden, Utah.)

DALE, J., AND MCCOMB, A. L.
1955. *Chlorosis, mycorrhizae*, and the growth of pines on a high-lime *soil*. Forest Sci. 1: 148–157.
DAVIS, WILLIAM C.
1940. Abhor alkaline sands. U.S. Forest Serv. Planting Quart. 9: 18–20.
——— AND LATHAM, DENNIS H.
1939. Cedar blight on wilding and forest tree nursery stock. Phytopath. 29: 991–992.
——— WRIGHT, ERNEST, AND HARTLEY, CARL.
1942. Diseases of forest-tree nursery stock. U.S. Fed. Security Agency, Civ. Conserv. Corps Forestry Pub. 9, 79 pp., illus.
DAYHARSH, V. J.
1934. Stratification vs. scarification for cedar seed. U.S. Forest Serv. Planning Quart. 3: 15–16.
DEFFENBACHER, FORREST W., AND WRIGHT, ERNEST.
1954. Refrigerated storage of conifer seedlings in the Pacific Northwest. Jour. Forestry 52: 936–938.
DEGRYSE, J. J.
1924. Injurious shade tree insects of the Canadian prairies. Canada Dept. Agr. Pam. 47, 23 pp., illus.
DEJARNETTE, G. M.
1936. Annual planting report. U.S. Forest Serv., Region 1, 72 pp.
———
1938. Annual planting report. U.S. Forest Serv., Region 1, 89 pp.
——— AND AUGENSTEIN, J. W.
1946. Annual planting and nursery report. U.S. Forest Serv., Region 1, 21 pp.
DENGLER, ALFRED.
1944. Waldbau. Ed. 3, 596 pp., illus. Berlin: Springer Verlag.
DOWNS, JOE A.
1954. Square pots for transplants. U.S. Forest Serv. Tree Planters' Notes 16: 10–16, illus.
DUFFIN, ROBERT B.
1955. Irrigation water from wells. Okla. Agr. Col. Ext. Serv. Cir. 645, 27 pp., illus.
ENGSTROM, ALBERT.
1950. Mulching seedbeds with cellophane. Jour. Forestry 48: 283.
———
1955. Polyethylene film for seedbed mulch. U.S. Forest Serv. Tree Planters' Notes 21: 26–27.
ENGSTROM, HAROLD E.
1941. Utilizing the warehouse for storage of conifers. U.S. Forest Serv. Planting Quart. 10: 14.
——— AND STOECKELER, J. H.
1941. Nursery practice for trees and shrubs suitable for planting on the Prairie Plains. U.S. Dept. Agr. Misc. Pub. 434, 159 pp., illus.
FARNSWORTH, C. E., LEA, R. V., AND ENGELKEN, JOHN.
1956. Mulching coniferous transplant beds with sawdust. U.S. Forest Serv. Tree Planters' Notes 25: 4–7.
FASSETT, NORMAN C.
1944. *Juniperus virginiana, J. horizontalis,* and *J. scopulorum*. Torrey Club Bul. 71: 410–418.
FEUSTEL, IRVIN C.
1938. The nature and use of organic amendments. U.S. Dept. Agr. Yearbook 1938: 462–468.
FISCHBACH, P. E., SCHLEUSENER, P. E., AND DREESZEN, V. H.
1957. Nebraska minimum standards for artificially gravel packed irrigation wells. Nebr. Agr. Expt. Sta. Ext. Cir. 57–702, 18 pp., illus.
FLEMION, F.
1941. Further studies of the rapid determination of the germinative capacity of seeds. Boyce Thompson Inst. Contrib. 11: 455–464.
FOGEL, MARTIN.
1957. Selection of pumping equipment for irrigation. S. Dak. Agr. Ext. Serv. Cir. 503 (Rev.), 16 pp., illus.
FOOD AND AGRICULTURAL ORGANIZATION.
1954. Soil-potta press. FAO Equip. Note A–3, 1 p.
FOSTER, A. A.
1959. Nursery diseases of southern pines. U.S. Forest Serv., Forest Pest Leaflet 32, 7 pp., illus.
FOSTER, C. H.
1932. Technical forest practices in New York—improvements in planting stock production. Jour. Forestry 30: 791–799.
FOWELLS, H. A.
1943. The effect of certain growth substances on root-pruned ponderosa pine seedlings. Jour. Forestry 41: 685–686.
———
1953. The effect of seed and stock size on survival and early growth of ponderosa and Jeffrey pine. Jour. Forestry 51: 504–507.
——— AND SCHUBERT, G. H.
1953. Planting stock storage in the California pine region. U.S. Forest Serv. Calif. Forest and Range Expt. Sta. Tech. Paper 3, 12 pp.
FOX, J. W.
1937. Annual nursery report. U.S. Forest Serv., Savenac Nursery, Haugan, Mont., 55 pp., illus.
———
1939. Annual nursery report. U.S. Forest Serv., Savenac Nursery, Haugan, Mont., 55 pp., illus.
———
1940. Improved transplanting equipment. U.S. Forest Serv. Planting Quart. 9: 7–8.
FREAR, D. E. H.
1959. Pesticide handbook. Ed. 11, 249 pp. State College, Pa.: Col. Sci. Pub.
FUTRELL, L. M.
1959. Seedbed smoother. U.S. Forest Serv. Tree Planters' Notes 38: 1, illus.
GAMBRELL, F. L., AND HEIT, C. H.
1952. Soil chemicals in evergreen seedbeds. Amer. Nurseryman 95 (10): 9–10, illus.
GARLOUGH, F. E., AND SPENCER, DONALD A.
1944. Control of destructive mice. U.S. Fish and Wildlife Serv. Conserv. Bul. 36, 37 pp., illus.
GEORGE, ERNEST J.
1939. Tree planting on the drier sections of the Northern Great Plains. Jour. Forestry 37: 695–698.
———
1953. Tree and shrub species for the Northern Great Plains. U.S. Dept. Agr. Cir. 924, 46 pp., illus.
———
1957. Shelterbelts for the Northern Great Plains. U.S. Dept. Agr. Farmer's Bul. 2109, 16 pp., illus.
GOODFELLOW, VANCE V., AND COLBERG, W. J.
1958. Insect pests of evergreens. N. Dak. Agr. Col., Cir. A–297, 5 pp., illus.
GOSS, R. W.
1960. Mycorrhizae of ponderosa pine in Nebraska grassland soils. Nebr. Agr. Expt. Sta. Res. Bul. 192, 47 pp., illus.
GRAHAM, S. A.
1939. Principles of forest entomology. Ed. 2, 410 pp., illus. New York.
GRAHAM, SAMUEL A., AND BAUMHOFER, LYNN G.
1927. The pine tip moth in the Nebraska National Forest. Jour. Agr. Res. 35: 323–333.
GREB, B. W., AND BLACK, Al.
1961. Effect of windbreak plantings on adjacent crops. Jour. Soil and Water Conserv. 16: 223–227.
HAAS, H. G., AND EVANS, C. E.
1957. Nitrogen and carbon changes in Great Plains soils as influenced by cropping and soil treatments. U.S. Dept. Agr. Tech. Pub. 1164, 11 pp., illus.
HAASIS, F. W.
1914. Result of an experiment on the effect of drying in the roots of seedlings of red and white pine. Forestry Quart. 12: 311–318.
HAERTL, E. J.
1955. New horizons in the application of chelation to agriculture. Down to Earth Mag. 2 (1): 6–9, illus.

HALL, MARION TRUFANT.
1952. Variation and hybridization in *Juniperus*. Ann. Mo. Bot. Garden 39: 1–64, illus.
HALL, RALPH C.
1936. Control of the Nantucket pine tip moth in the Central States. U.S. Bur. Ent. and Plant Quart., 5 pp.
HANKS, SIDNEY H.
1962. A seven-row seedling transplanter for nursery use. U.S. Forest Serv. Tree Planters' Notes 53: 20–22.
HANSEN, N. E.
1930. Evergreens in South Dakota. S. Dak. Agr. Expt. Sta. Bul. 254, 33 pp., illus.
HARTLEY, C.
1915. Injury by disinfectants to seeds and roots in sandy soils. U.S. Dept. Agr. Bul. 169, 35 pp., illus.
———
1917. The control of damping off of coniferous seedlings. U.S. Dept. Agr. Bul. 453, 32 pp., illus.
———
1918. Stem lesions caused by excessive heat. Jour. Agr. Res. 14: 595–604.
———
1921. Damping-off in forest nurseries. U.S. Dept. Agr. Bul. 934, 99 pp., illus.
———
1935a. Prevention of diseases of conifers in nurseries and plantations. U.S. Bur. Plant Indus., 27 pp.
———
1935b. Undesirable practices from the standpoint of effect on damping-off liability. U.S. Forest Serv. Planting Quart. 4 (2), 16 pp.
HARVEY, R. B.
1930. Length of exposure to low temperature as a factor in the hardening process in tree seedlings. Jour. Forestry 28: 50–53, illus.
HASTINGS, W. G.
1923. Revolutionizing nursery practice. Jour. Forestry 21: 180–182.
HEIT, C. E.
1955. The excised embryo method for testing germination quality of dormant seed. N.Y. State Agr. Expt. Sta. Jour. Paper 1013: 108–117.
HERMAN, F. R.
1958. Silvical characteristics of Rocky Mountain juniper. U.S. Forest Serv. Rocky Mountain Forest and Range Expt. Sta. Paper 29, 20 pp., illus. (Fort Collins, Colo.)
HIGGINS, JAY.
1928. Effect of density on seedling development. Jour. Forestry 26: 909–912.
HILL, JOSEPH A.
1955. Methyl bromide gas controls weeds, nematodes, and root rots in seedbeds. U.S. Forest Serv. Tree Planters' Notes 21: 11–14.
HODGES, CHARLES S., JR.
1962. Diseases in southeastern forest nurseries and their control. U.S. Forest Serv. Southeast. Forest Expt. Sta. Paper 142, 16 pp., illus. (Asheville, N.C.)
HOLMES, G. D., AND BUSZEWICZ, G.
1958. The storage of seed of temperate forest tree species. Forestry Abs. 19: 455–476.
——— AND IVENS, G. W.
1952. Chemical control of weeds in forest nursery seedbeds. Great Britain Forest. Comm., Forest Rec. 13, 31 pp., illus.
HOLMES, R. E., AND BROWN, J. C.
1957. Iron and soil fertility. U.S. Dept. Agr. Yearbook 1957: 111–115.
HOWELL, J. R.
1932. The development of seedlings of ponderosa pine in relation to soil types. Jour. Forestry 30: 944–947.
HUTCHISON, S. B., AND KEMP, P. D.
1952. Forest resources of Montana. U.S. Forest Serv. Forest Resource Rpt. 5, 76 pp., illus.
IMPERIAL INSTITUTE OF LONDON.
1936. Some minor mineral fertilizer materials. Imp. Inst. London Bul. 34 (2): 212–219.
JANOUCH, KARL L.
1927. Effect of spacing and root pruning on the development of transplants. Jour. Forestry 25: 62–67.
JOHNSEN, THOMAS N., JR.
1959. Longevity of stored juniper seeds. Ecol. 40: 487–488.
JOHNSON, E. W.
1955. A simple device for making paper pots. U.S. Forest Serv. Tree Planters' Notes 20: 11–13, illus.
——— AND VANDERSLICE, G. G.
1956. An improved device for making paper pots. U.S. Forest Serv. Tree Planters' Notes 24: 3–5, illus.
JOHNSON, PHILLIP C.
1958. Spruce spider mite infestations in northern Rocky Mountain Douglas-fir forests. U.S. Forest Serv., Intermountain Forest and Range Expt. Sta. Res. Paper 55, 14 pp., illus. (Ogden, Utah.)
JONES, D. L., GAINES, FRANK, AND KARPER, R. E.
1932. Trees and shrubs in northwest Texas. Tex. Agr. Expt. Sta. Bul. 447, 63 pp., illus.
JONES, G. W.
1925. Forest nursery working practice at Savenac Nursery. Jour. Forestry 23: 635–644.
———
1934. Spring sowing versus fall sowing white spruce—Rhinelander Nursery. U.S. Forest Serv. Planting Quart. 3: 14.
JORDAN, HOWARD V., AND REISENAUER, H. M.
1957. Sulphur and soil fertility. U.S. Dept. Agr. Yearbook 1957: 107–110, illus.
KALELA, AARNO.
1937. Zur Synthese der experimentellen Untersuchungen über Klimarassen der Holzarten. Forest Res. Inst. Finland, Pub. 26, 445 pp., illus.
KEEN, F. P.
1952. Insect enemies of western forests. U.S. Dept. Agr. Misc. Pub. 273, 280 pp., illus.
KELLEY, ARTHUR PIERSON.
1930. II. Mycorhiza studies. The duration of certain pine mycorhizae. Jour. Forestry 28: 849–852.
KIENITZ, M.
1922. Ergebnis der Versuchsanpflanzung von Kiefern verschiedener Herkunft in der Oberförsterei Chorin. Zeitschr. Fur. Forst-und Jagdw. 54: 65–93. (German.)
KNIGHT, H.
1956. Growning green manure crops at a forest nursery. U.S. Forest Serv. Tree Planters' Notes 24: 19–23, illus.
———
1958. A test to determine acceptability of sawdust as a seed bed cover. U.S. Forest Serv. Tree Planters' Notes 31: 10–14, illus.
KOPITKE, J. C.
1941. The effect of potash salts upon the hardening of coniferous seedlings. Jour. Forestry 39: 555–558.
KORSTIAN, C. F., HARTLEY, CARL, WATTS, L. F., AND HAHN, GLENN G.
1921. A chlorosis of conifers corrected by spraying with ferrous sulfate. Jour. Agr. Res. 21: 153–171, illus.
LANGLET, OLOF.
1936. Study of the physiological variability of pine and its relation to the climate. Meddelanden från Statens Skogsförsöksanstalt 29 (4–6): 421–470. (Translations of the German Sum. 293 by C. F. DeBlumenthal, U.S. Forest Serv. Div. Silvics, 89 pp.)
LANQUIST, KARL B.
1945. Leaf litter in forest nurseries. Jour. Forestry 43: 43–44, illus.
———
1946. Tests of forest tree seed in California. Jour. Forestry 44: 1063–1066.
———
1951. Allyl alcohol application through the overhead sprinkler system. U.S. Forest Serv. Tree Planters' Notes 7: 12–13, illus.

LANQUIST, KARL B.
1954a. Seedling harvester. U.S. Forest Serv. Tree Planters' Notes 16: 5–6, illus.
——— 1954b. Seed cleaning and dewinging machine. U.S. Forest Serv. Tree Planters' Notes 18: 8–9, illus.
LEVITT, J.
1956. The hardiness of plants. 278 pp., illus. New York.
LITTLE, ELBERT L., JR.
1950. Southwestern trees, a guide to the native species of New Mexico and Arizona. U.S. Dept. Agr., Agr. Handb. 9, 109 pp., illus.
——— 1953. Check list of native and naturalized trees of the United States (including Alaska). U.S. Dept. Agr., Agr. Handb. 41, 472 pp.
LIVINGSTON, R. B.
1949. An ecological study of the Black Forest, Colorado. Ecol. Monog. 19: 124–144, illus.
MCARDLE, RICHARD E.
1932. The relation of mycorrhizae to conifer seedlings. Jour. Agr. Res. 44: 287–316, illus.
MCCOMB, A. L.
1943. Mycorrhizae and phosphorus nutrition of pine seedlings in a prairie soil nursery. Iowa Agr. Expt. Sta. Res. Bul. 314: 582–612, illus.
MCDANIEL, VERN E.
1954. Roto-tiller cultivator. U.S. Forest Serv. Tree Planters' Notes 18: 13–15, illus.
MCDERMOTT, R. E., AND FLETCHER, P. W.
1955. Influence of light and nutrition on color and growth of redcedar seedlings. Univ. Mo. Agr. Expt. Sta. Bul. 587, 15 pp., illus.
MAKI, T. E.
1940. Seed maturity in ponderosa pine. Jour. Forestry 38: 55–60.
——— AND ALLEN, R. M.
1952. Use of allyl alcohol for weed control in forest nurseries. Jour. Forestry 50: 470–471.
MANN, W. F., JR., AND KINGSLEY, C. E.
1958. Bird control in forest nurseries. U.S. Forest Serv. South. Forest Expt. Sta., South. Forestry Notes 113. (New Orleans, La.)
MATKIN, O. A., AND CHANDLER, PHILLIP, A.
1957. U.C. type soil mixes for container-grown plants. Univ. Calif. Agr. Expt. Sta. Ext. Serv. Leaflet 89, 2 pp.
MAYER-KRAPOLL, HERMANN.
1956. The use of commercial fertilizers—particularly nitrogen in forestry. Translated and published by Nitrogen Div. Allied Chemical and Dye Corp., 111 pp., illus. (German.) New York, N.Y.
MEINECKE, E. P.
1929. Experiments with repeating pine rusts. Phytopath. 19: 327–342.
MEINES, M. K.
1939. Broadcast versus drill sowing of conifers. U.S. Forest Serv. Planting Quart. 8: 3.
MELIN, E.
1927. Studies of the development of coniferous plants in rawhumus. II. The development of mycorrhiza on pine seedlings in various forms of rawhumus. Meddel. från Statens Skogsförsöksanstalt. 23: 433–486. (Swedish.) (Translation by Paul Stickel.)
MIROV, N. T.
1936. A note on germination methods for coniferous species. Jour. Forestry 34: 719–723.
MONSON, O. W.
1952. Sprinkler irrigation in Montana. Mont. State Col. Agr. Expt. Sta. Bul. 483, 40 pp., illus.
——— CRIDDLE, WAYNE D., AND DAVIS, STERLING.
1953. Estimated water requirement of crops in irrigated areas of Montana. Mont. State Col. Agr. Expt. Sta. Bul. 494, 23 pp., illus.
MONY, CHARLES C.
1935. Leveling a new nursery. U.S. Forest Serv. Planting Quart. 4: 20.
——— 1941. Top and root pruning cleaver. U.S. Forest Serv. Planting Quart. 10: 25, illus.
——— 1954. Vallonia rotary tooth cultivator. U.S. Forest Serv. Tree Planters' Notes 16: 17–20, illus.
——— 1958. Seed pelleting process for bird and disease control. U.S. Forest Serv. Tree Planters' Notes 32: 7–8.
——— 1961. Observations on the use of methyl bromide. U.S. Forest Serv. Tree Planters' Notes 45: 23.
MOORE, O. W.
1960. Ammonium nitrate fertilizer can explode. U.S. Forest Serv. Tree Planters' Notes 41: 3–4.
MULLINS, R. E.
1956. Moisture retaining materials for nursery stock packaging. Ontario Dept. Lands and Forest Res. Rpt. 34, 43 pp., illus.
MUNGER, T. T.
1941. Regional strains of ponderosa pine show pronounced difference. U.S. Forest Serv. Planting Quart. 10 (1): 30.
MUNNECKE, DONALD E.
1957. Chemical treatment of nursery soils. *In* The U.C. system for producing healthy container-grown plants. Calif. Agr. Expt. Sta. Manual 23: 197–209.
NIENSTAEDT, HANS.
1957. Silvical characteristics of white spruce. U.S. Forest Serv., Lake States Forest Expt. Sta. Paper 55, 23 pp., illus. (St. Paul, Minn.)
NIKIFOROFF, CONSTANTIN C.
1938. Soil organic matter and soil humus. U.S. Dept. Agr. Yearbook 1938: 929–939.
NORUM, E. B., KRANTZ, B. A., AND HAAS, H. J.
1957. The Northern Great Plains. U.S. Dept. Agr. Yearbook 1957: 494–504.
OLIVER, D. A.
1937. Improvements on Yale transplant board. U.S. Forest Serv. Planting Quart. 6 (3): 26, illus.
OLSON, D. S.
1930. Growing trees for forest planting in Montana and Idaho. U.S. Dept. Agr. Cir. 120, 92 pp., illus.
ON, DANNY.
1952. 2,3,5-triphenyl tetrazolium chloride as a viability indicator of certain coniferous seeds. Jour. Forestry 50: 868.
OVER, WILLIAM H.
1932. Flora of South Dakota. Univ. S. Dak., 161 pp., illus.
PACK, DEAN A.
1921. After-ripening and germination of juniperus seed. Bot. Gaz. 71: 32–60.
PARKER, J. R., AND COWAN, F. T.
1953. Grasshopper control. U.S. Dept. Agr. PA–149, 8 pp.
PEARSON, G. A.
1914. Forest planting in Arizona and New Mexico. Soc. Amer. Foresters Proc. 9: 457–458.
PETERSON, L. O. T., AND WORDEN, H. A.
1959. Summary report. Canada Dept. Agr., Res. Branch, Forest Nursery Sta., Indian Head, Saskatchewan, pp. 7–10.
PIETERS, A. J., AND MCKEE, ROLAND.
1938. The use of cover and green-manure crops. U.S. Dept. Agr. Yearbook 1938: 431–444.
PIKE, GALEN W.
1933. Temperature only one factor in storing nursery stock. U.S. Forest Serv. Planting Quart. 2 (2).
PLANK, DONALD K.
1939. Root response of slash pine seedlings to indolebutyric acid. Jour. Forestry 37: 497–498, illus.
POTTER, L. D.
1952. North Dakota's heritage of pine. N. Dak. Hist. 19: 157–166, illus.

POTTS, S. F.
1952. Control of forest and shadetree insects with concentrated sprays applied by mist blowers. *In* Important tree pests of the Northeast, pp. 170–174, illus. Soc. Amer. Foresters, New England Sect., Concord, N.H.
——— AND WATERMAN, A. M.
1952. Spraying and dusting to control insects and diseases. *In* Important tree pests of the Northeast, pp. 166–170, illus. Soc. Amer. Foresters, New England Sect., Concord, N.H.
PRENTICE, R. M., AND HILDAHL, V.
1959. Provinces of Manitoba and Saskatchewan, forest insect survey, annual report. Forest Insect and Dis. Survey, Forest Biol. Div., Sci. Serv., pp. 82–92.
PRITCHARD, A. EARL, AND BAKER, EDWARD W.
1955. A revision of the spider mite family Tetranychidae. Pacific Coast Ent. Soc., San Francisco, Calif., 472 pp., illus.
READ, RALPH A.
1955. Grading of transplants may improve initial survival of ponderosa pine in Plains windbreaks. U.S. Dept. Agr., Rocky Mountain Forest and Range Expt. Sta. Res. Note 16, 2 pp. (Ft. Collins, Colo.)
———
1958. The Great Plains Shelterbelt in 1954. Great Plains Agr. Council Pub. 16, Bul. 441: 125 pp., illus.
RICHARDS, L. A., *et al.*
1954. Diagnosis and improvement of saline and alkaline soils. U.S. Dept. Agr., Agr. Handb. 60, 160 pp., illus.
ROBBINS, P. W.
1932. Use of paper mulch in the nursery. Jour. Forestry 30: 415–418.
———
1935. An iron seedbed stake for forest nurseries. Jour. Forestry 33: 440–441.
———
1942. A grading and counting machine for forest nursery seedlings. Jour. Forestry 40: 809–811.
——— GRIGSBY, B. H., AND CHURCHILL, B. R.
1947. Report on chemical weed control for conifer seedlings and transplants. Mich. Agr. Expt. Sta. Quart. Bul. 30: 237–240, illus.
ROESER, JACOB, JR.
1932. Transpiration capacity of coniferous seedlings and the problem of heat injury. Jour. Forestry 30: 381–395.
———
1940. The water requirements of Rocky Mountain conifers. Jour. Forestry 38: 24–26.
———
1941. Some aspects of flower and cone production in ponderosa pine. Jour. Forestry 39: 534–536, illus.
ROGERS, T. HAYDEN, AND GIDDENS, JOEL E.
1957. Green manure and cover crops. U.S. Dept. Agr. Yearbook 1957: 252–257.
ROSENDAHL, R. O.
1942. The effect of mycorrhizal and non-mycorrhizal fungi on the availability of difficultly soluble potassium and phosphorus. Soil Sci. Soc. Amer. Proc. 7: 477–479, illus.
——— AND WILDE, S. A.
1942. Occurrence of ectotropic mycorrhizal fungi in soil of cut-over areas and sand dunes. Ecol. Soc. Amer. Bul. 23: 73–74.
ROSS, NORMAN M.
1937. Dominion forest nursery station's results of experiments 1932–1936, inclusive. Canada Dept. Agr. Pub., 18 pp., illus.
RUDOLF, PAUL O.
1952. Low temperature seed storage for western conifers. U.S. Forest Serv., Lake States Forest Expt. Sta. Misc. Rpt. 20, 8 pp. (St. Paul, Minn.)
———
1956. Guide for selecting superior forest trees and stands in the Lake States. U.S. Forest Serv., Lake States Forest Expt. Sta. Paper 40, 33 pp., illus. (St. Paul, Minn.)
RUSSEL, DARRELL A.
1957. Boron and soil fertility. U.S. Dept. Agr. Yearbook 1957: 121–128.
SAF SEED CERTIFICATION SUBCOMMITTEE.
1963. The seed we use: Part II. How to assure reliable information about it. Jour. Forestry 61: 265–269, illus.
SALTER, ROBERT M., AND SCHOLLENBERGER, C. J.
1938. Farm manure. U.S. Dept. Agr. Yearbook 1938: 445–461, illus.
SCHNEIDER, H. W.
1937. Pruning roots hastens hardening-off of jack pine. U.S. Forest Serv. Planting Quart. 6 (3): 1.
SCHRADER, W. H.
1938. The evolution of the transplant board at the Monument nursery. U.S. Forest Serv. Planting Quart. 7 (4): 18–19.
SCHUBERT, G. H.
1954. Viability of various coniferous seeds after cold storage. Jour. Forestry 52: 446–447.
SHARKEY, T. M.
1956. Sheltering the seedbed. U.S. Forest Serv. Tree Planters' Notes 25: 11.
SHAW, DALE L.
1963. A homemade tree potting system. U.S. Forest Serv. Tree Planters' Notes 61: 17–18.
SHEMAHANOVA, N. M.
1957. Role of mycorrhiza-forming fungi in the nutrition of woody plants. Rev. of Applied Mycology 36–12, p. 777. (Translation.)
SHIRLEY, H. L.
1936. Lethal high temperatures for conifers and the cooking effect of transpiration. Jour. Agr. Res. 53: 239–258.
——— AND MEULI, L. J.
1939. Influence of moisture supply on drought resistance of conifers. Jour. Agr. Res. 59: 1–22.
SHOW, S. B.
1917. Effect of depth of covering seed upon the germination and quality of stock. Jour. Forestry 15: 619–623.
SLAGG, C. M., AND WRIGHT, E.
1942. Diplodia epidemic in conifer seedbeds. Phytopath. (Abs.) 32: 16.
——— AND WRIGHT, E.
1943. Diplodia blight in coniferous seedbeds. Phytopath. 33: 390–393.
SOWASH, R. O.
1936. Cold storage of seedlings and its effect upon survival in the field. U.S. Forest Serv. Planting Quart. 5 (4): 9–11.
———
1954. Agitator type mechanical tree lifter. U.S. Forest Serv. Tree Planters' Notes 18: 10–12, illus.
SPEERS, CHARLES F., AND SCHMIEGE, DONALD C.
1961. White grubs in forest tree nurseries and plantations. U.S. Forest Serv., Forest Pest Leaflet 63, 4 pp., illus.
STADTHERR, R. J., AND COULTAS, C. L.
1961. Chemical weed control in the nursery. Minn. Nurserymen's Newsletter 9 (3, 4): 1–4.
STEAVENSON, HUGH A.
1940. The hammermill as an important nursery implement. Jour. Forestry 38: 356–361, illus.
———
1952. Experiences in using allyl alcohol for weed control. U.S. Forest Serv. Tree Planters' Notes 12: 7.
STEWART, I., AND LEONARD, C. D.
1952. Chelates as sources of iron for plants growing in the field. Science 116: 564–566.
STOECKELER, J. H.
1939. Nursery soil moisture content. U.S. Forest Serv. Planting Quart. 8 (3): 9–12.
———
1946. Alkali tolerance of drought-hardy trees and shrubs in the seed and seedling stage. Minn. Acad. Sci. Proc. 14: 79–83.

STOECKELER, J. H.
——— 1951a. Proper watering in the nursery produces drought-hardy jack pine. U.S. Forest Serv. Lake States Forest Expt. Sta. Tech. Note 348, 1 p. (St. Paul, Minn.)
——— 1951b. Hydrocarbon content and storage period affect toxicity of mineral spirits used as selective herbicides for red pine nursery beds. Jour. Forestry 49: 647–649.
——— 1951c. Killing weed seeds. Amer. Nurseryman 93 (8): 10.
——— 1952a. A northeastward extension of the range of Douglas-fir. Jour. Forestry 50: 393.
——— 1952b. Control of weeds in forest nurseries with mineral spirits. Adv. in Chem. 7: 84–90.
——— AND AAMODT, EINAR.
1940. The use of tensiometers in regulating watering in forest nurseries. Plant Physiol. 15: 589–607, illus.
——— AND ARNEMAN, HAROLD F.
1960. Fertilizers in forestry. Adv. in Agron. 12: 127–195, illus. New York.
——— AND BASKIN, L. C.
1937. The Denbigh disk scarifier, a new method of seed treatment. Jour. Forestry 35: 396–398, illus.
——— AND JONES, G. W.
1957. Forest nursery practice in the Lake States. U.S. Dept. Agr., Agr. Handb. 110, 124 pp., illus.
——— ROE, E. I., AND SOWASH, R. O.
1951. Allyl alcohol for weed control in forest nurseries. U.S. Forest Serv. Tree Planters' Notes 7: 10–12.
——— AND RUDOLF, PAUL O.
1949. Winter injury and recovery of conifers in the Upper Midwest. U.S. Forest Serv., Lake States Forest Expt. Sta. Paper 18, 20 pp. (St. Paul, Minn.)
——— AND RUDOLF, PAUL O.
1956. Winter coloration and growth of jack pine in the nursery as affected by seed source. Zeitschr. f. Forstgenetik u. Forstpflanzenzüchtung 5: 161–165, illus.
STONE, EDWARD C.
1955. Poor survival and the physiological condition of planting stock. Forest Sci. 1: 90–94.
STORY, H. D., JR.
1940. Nursery bed shaper. Jour. Forestry 38: 515–517.
STRONG, FORREST C.
1952. Damping-off in the forest tree nursery and its control. Mich. Agr. Expt. Sta. Quart. Bul. 34: 285–296, illus.
SUDWORTH, GEORGE B.
1915. The cypress and juniper trees of the Rocky Mountain region. U.S. Dept. Agr. Bul. 207, 36 pp., illus.
SWENK, M. H.
1927. The pine tip moth in the Nebraska National Forest. Nebr. Agr. Expt. Sta. Res. Bul. 40: 5–50, illus.
TAYLOR, CARL A.
1941. Germination behavior of tree seeds as observed in the regular handling of seed at the seed extractory and nursery, Norfolk, Nebraska. U.S. Forest Serv., Prairie States Forestry Proj., 64 pp., illus.
TENNESSEE VALLEY AUTHORITY.
1954. Operation manual for TVA forest nurseries. Tenn. Val. Authority, Div. of Forestry Relat. Pub., 57 pp., illus.
THEIGS, B. J.
1955. Effect of soil fumigation on nitrification. Down to Earth Mag. 11 (1): 14–15.
THOMAS, R. W.
1953. Provinces of Manitoba and Saskatchewan forest service survey. Canada Dept. Agr. Ann. Rpt. Forest Insect and Dis. Survey, pp. 104–111.
THORFINNSON, T. S., HUNT, MERYL, AND EPP, A. W.
1955. Cost of distribution of irrigation water by different methods. Nebr. Agr. Expt. Sta. Bul. 432, 28 pp., illus.
TOUMEY, JAMES W., AND KORSTIAN, CLARENCE F.
1942. Seeding and planting in the practice of forestry. Ed. 3, 520 pp., illus. New York.
TRUOG, E.
1946. Soil reaction influence on availability of plant nutrients. Soil Sci. Soc. Amer. Proc. 11: 305–306, illus.
UMLAND, CHARLES B.
1946. Nursery weeding costs reduced by mechanical cultivation. Jour. Forestry 44: 379–380, illus.
U.S. FOREST SERVICE.
1936. Seed and nursery practice. Shelterbelt Proj. Pub., 127 pp., illus.
——— 1948. Woody-plant seed manual. U.S. Dept. Agr. Misc. Pub. 654, 416 pp., illus.
U.S. FOREST SERVICE CALIFORNIA FOREST EXPERIMENT STATION.
1954. Annual report, forest research in California. 70 pp., illus. (Berkeley, Calif.)
U.S. FOREST SERVICE LAKE STATES FOREST EXPERIMENT STATION.
1937. Watering reduces soil-surface temperatures. Tech. Note 126: 2 pp., illus. (St. Paul, Minn.)
U.S. FOREST SERVICE ROCKY MOUNTAIN REGION.
1931. Annual planting report. 41 pp. (Denver, Colo.)
U.S. FOREST SERVICE SOUTHERN FOREST EXPERIMENT STATION.
1940. Forest type map of Oklahoma. (New Orleans, La.)
VAN SLYKE, L. L.
1932. Fertilizers and crop production. 493 pp., illus. New York.
VOIGT, G. K.
1953. The effect of fungicides, insecticides, herbicides, and fertilizer salts on respiration of root tips of tree seedlings. Soil Sci. Soc. Amer. Proc. 17: 150–152.
——— 1955. The effect of applied fungicides, herbicides, and insecticides on the control of nutrient elements in tissue of coniferous seedlings. Soil Sci. Soc. Amer. Proc. 19: 237–239.
——— STOECKELER, J. H., AND WILDE, S. A.
1958. Response of coniferous seedlings to soil applications of calcium and magnesium fertilizers. Soil Sci. Soc. Amer. Proc. 22: 343–345.
WAHLENBERG, W. G.
1925. Forestation research in Montana and north Idaho. Jour. Forestry 23: 588–599.
——— 1929. Relation of quantity of seed sown and density of seedlings to the development and survival of forest planting stock. Jour. Agr. Res. 38: 219–227.
——— 1930. Investigations in weed control by zinc sulphate and other chemicals at the Savenac Forest Nursery. U.S. Dept. Agr. Tech. Bul. 156, 36 pp., illus.
WAKELEY, PHILIP C.
1954. Planting the southern pines. U.S. Dept. Agr. Monog. 18, 233 pp., illus.
WALKER, JOHN, AND KERR, W. L.
1954. Dominion forest nursery station's progress report 1947–1952. Canada Dept. Agr. Pub., 40 pp., illus.
WARE, E. R.
1936. Forests of South Dakota—their economic importance and possibilities, U.S. Forest Serv., Lake States Forest Expt. Sta. (St. Paul, Minn.) and S. Dak. Planning Bd., 28 pp., illus.
WARNER, J. R., AND CHASE, C. D.
1956. The timber resource of North Dakota. U.S. Forest Serv., Lake States Forest Expt. Sta. Paper 36, 39 pp., illus. (St. Paul, Minn.)
WEAVER, J. E., AND ALBERTSON, F. W.
1956. Grasslands of the Great Plains. Ed. 1, 348 pp., illus. Lincoln, Nebr.

WEIDMAN, R. N.
1939. Evidences of racial influences in a 25-year-old test of ponderosa pine. Jour. Agr. Res. 59: 855–888.
WHITE, DONALD P.
1941. Prairie soil as a medium for tree growth. Ecology 22: 397–407, illus.
——— AND LEAF, ALBERT L.
1956. Forest fertilization. N.Y. State Univ. Col. Forestry Tech. Pub. 81, 305 pp.
WIERSMA, JOHN L.
1955. Effect of wind variation on water distribution from rotating sprinklers. S. Dak. Agr. Expt. Sta. Tech. Bul. 16, 18 pp., illus.
———
1956. A B C's of sprinkler irrigation. S. Dak. Agr. Expt. Sta. Cir. 95, 31 pp., illus.
WILDE, S. A.
1946. Difficultly soluble sources of nutrients; their use in forest nurseries. Jour. Forestry 44: 1082–1086.
———
1958. Forest soils. 537 pp., illus. New York.
——— AND PERSIDSKY, D. J.
1956. Effect of biocides on the development of ectotrophic mycorrhizae in Monterey pine seedlings. Soil Sci. Soc. Amer. Proc. 20: 107–110.
——— AND VOIGT, G. K.
1955. Analysis of soils and plants for foresters and horticulturists. 117 pp., illus., Ann Arbor, Mich.
WILLIAMSON, M. J.
1957. Silvical characteristics of eastern redcedar. Central States Forest Expt. Sta. Misc. Release 15, 14 pp., illus. (Columbus, Ohio)
WOODIN, H. E., AND LINDSEY, A. A.
1954. Juniper-pinyon east of the Continental Divide, as analyzed by the linestrip method. Ecology 35: 474–489, illus.
WOODWARD, G. O., AND GILDEN, ROBERT O.
1955. Successful sprinkler irrigation. Wyo. Agr. Ext. Serv. Cir. 141, 12 pp., illus.
WRIGHT, E., AND WELLS, H. R.
1948. Tests on the adaptability of trees and shrubs to shelterbelt planting on certain phymatotrichum root-rot infested soils of Oklahoma and Texas. Jour. Forestry 46: 256–262, illus.
WYCOFF, H. B.
1952. Green manure crop causes seedling mortality. U.S. Forest Serv. Tree Planters' Notes 12: 9–10.
WYCOFF, HUGH.
1954. An analysis of nursery stock production costs in relation to the use of mineral spirits. U.S. Forest Serv. Tree Planters' Notes 18: 25–28.
WYGANT, N. D.
1936. Insect control in shelterbelts on the Great Plains. U.S. Bur. Ent. and Plant Quart., 51 pp.

APPENDIX

COMMON AND SCIENTIFIC NAMES OF TREES AND SHRUBS MENTIONED

Conifers

Arborvitae, oriental (Chinese)	*Thuja orientalis* L.
Cypress, Arizona	*Cupressus arizonica* Greene.
Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco.
Fir, balsam	*Abies balsamea* (L.) Mill.
Fir, Siberian	*Abies sibirica* Ledeb.
Juniper, alligator	*Juniperus deppeana* Steud.
Juniper, Ashe	*J. ashei* Buchholz.
Juniper, common	*J. communis* L.
Juniper, oldfield common	*J. communis* var. *depressa* Pursh.
Juniper, one-seed	*J. monosperma* (Engelm.) Sarg.
Juniper, Pinchot	*J. pinchotii* Sudw.
Juniper, Rocky Mountain	*J. scopulorum* Sarg.
Juniper, Utah	*J. osteosperma* (Torr.) Little.
Larch, European	*Larix decidua* Mill.
Larch, Siberian	*L. sibirica* Ledeb.
Pine, Austrian	*Pinus nigra* Arnold.
Pine, Digger	*P. sabiniana* Dougl.
Pine, Italian stone	*P. pinea* L.
Pine, jack	*P. banksiana* Lamb.
Pine, Japanese black	*P. thunbergi* Parl.
Pine, Japanese red	*P. densiflora* Sieb & Zucc.
Pine, Jeffrey	*P. jeffreyi* grev. and Balf.
Pine, limber	*P. flexilis* James.
Pine, loblolly	*P. taeda* L.
Pine, lodgepole	*P. contorta* Dougl.
Pine, ponderosa	*P. ponderosa* Laws.
Pine, red	*P. resinosa* Ait.
Pine, Scotch	*P. sylvestris* L.
Pine, shortleaf	*P. echinata* Mill.
Pine, Swiss stone	*P. cembra* L.
Pine, Virginia	*P. virginiana* Mill.
Pine, western white	*P. monticola* Dougl.
Pinyon	*P. edulis* Engelm.
Redcedar, eastern	*Juniperus virginiana* L.
Spruce, blue	*Picea pungens* Engelm.
Spruce, Engelmann	*P. engelmannii* Parry.
Spruce, Siberian	*P. obovata* Ledeb.
Spruce, Sitka	*P. sitchensis* (Bong.) Carr.
Spruce, white (includes Black Hills)	*P. glauca* (Moench) Voss.
Tamarack	*Larix laricina* (Du Roi) K. Koch.

Broadleaves

Cottonwood, eastern	*Populus deltoides* Bartr.
Elm, Chinese	*Ulmus parvifolia* Jacq.
Elm, Siberian	*U. pumila* L.
Oak, bur	*Quercus macrocarpa* Michx.
Peashrub, Siberian	*Caragana arborescens* Lam.
Rose, Japanese	*Rosa multiflora* Thunb.

SAFETY RULES AND PRECAUTIONS FOR HANDLING, MIXING, AND APPLYING CHEMICALS

Most insecticides and fungicides and some other sprays and baits contain poisons injurious, if not deadly, to humans and livestock. Many act through the skin or lungs as well as through the digestive tract. In addition, some are flammable or explosive, or involve other hazards. Wakeley (1954) lists some general rules which, if properly enforced, should minimize accidents occurring when poisons and other hazardous materials are handled. They are as follows:

1. Plainly mark both temporary and permanent containers to show nature of contents (poisonous, flammable, etc.) and date of purchase (some chemicals change or deteriorate with age). Keep dangerous materials tightly closed (unless their nature requires venting); out of reach of children, irresponsible persons, livestock, and pets; and in an adequately ventilated storeroom, preferably locked.

2. When mixing or applying poisonous materials, be extremely careful to keep them out of the mouth, eyes, nose, and lungs, and away from tender parts of the body. Ordinarily, wear leather or paraffined-cloth gloves (rubber or plastic gloves must be used with certain chemicals), and always wear goggles, a respirator, or a combination of the two. If the manufacturer specifies, mix substance only in open shed or outdoors.

3. Prohibit smoking during the mixing or application of flammable or explosive substances.

4. Burn or bury empty packages and bags that have contained poisons. Bury unused or discarded materials. When mixing vessels, sprayers, etc., are washed after use of the more poisonous substances, empty washwater into a hole in the ground, and fill in the hole. Do not burn empty arsenical containers except in open air. (Addition by authors: Avoid breathing smoke or fumes from burning empty chemical containers.)

5. Always wash hands and face thoroughly after mixing or applying poisonous substances. After long exposure, bathe and change clothes. Wash the clothes after each day's spraying.

6. Be sure that no poisonous spray material can get into domestic or livestock water supplies.

7. If sulfuric acid must be diluted (as for acidifying soil to control damping-off), always pour the acid, which is the heavier liquid, into the water. Water poured into sulfuric acid spatters badly, with serious danger, especially to the eyes.

Only the most responsible and trustworthy personnel should be allowed to handle chemicals that are explosive, flammable, or toxic to humans. It is extremely important that the directions on the labels on insecticides, fungicides, or weed killers be carefully read and followed. Containers for chemicals that have been emptied should be stored in a safe place or destroyed. Surplus mixtures should be buried and covered with soil. They should not be poured into streams or ponds where they may endanger human life, fish, or livestock.

Workers handling concentrated acid should be equipped with goggles, rubber gloves, and acidproof aprons. Once the acid is diluted to a 2-percent solution, it is not particularly hazardous to handle.

Workers should not breathe the fumes of chemicals, especially methyl bromide, allyl alcohol, and parathion (Frear 1959). In the manual application of methyl bromide, special injectors, as supplied or recommended by the manufacturer of the chemical, should be used. Masks or respirators should be worn when handling allyl alcohol, methyl bromide, Ferbam, and parathion.

Allyl alcohol, methyl bromide, chlordane, Ferbam, nicotine, and parathion should not be brought into contact with the skin. This precaution should also be observed when handling seedlings treated with such chemicals as Endrin and nicotine. These chemicals are used to repel rabbits after fieldplanting.

Some chemicals, such as carbon disulfide, are explosive. Others, such as chlorates and mineral spirits, are quite flammable. Ammonium nitrate (Moore 1960) and allyl alcohol are both explosive and flammable. Therefore, they must be stored in well-ventilated buildings well separated from warehouses and other buildings.

Certain insecticides are harmful to bees, which help pollinate many plants. If spraying with DDT is necessary, it should be done when the flowers are in the bud rather than the bloom stage. However, if the flowers are in bloom, toxaphene can be sprayed in the early morning or late evening.

Use of oil sprays in the summer is not recommended because the oil may injure the foliage or new growth of small nursery trees. In the dormant season, sprays should be thoroughly mixed or emulsified before application. Oil emulsions of more than 4 percent strength may damage trees. If oils or oil emulsions are used, tanks must, in most cases, be reasonably free of any lime sulfur residues, since these may break down the emulsion.

Many insecticides and fungicides tend to stain wood, painted surfaces, and stone. The stain damage caused by direct application or drift can be lessened by thoroughly wetting the object before and after an application.

Sprayers used for weed or brush killers, such as 2,4-D or 2,4,5-T, should not be used for spraying insecticides or fungicides in the nursery because minute residues of these chemicals may damage or kill the trees. If it is necessary to use these sprayers, they should be scrubbed out thoroughly with soap and water and rinsed repeatedly.

SPRAY FORMULAS FOR INSECTICIDES AND FUNGICIDES

A number of well-tested formulas have been developed for preparing insecticides and fungicides (tables 20 and 21). Use of these formulas will help nurserymen protect nursery beds as well as larger trees in windbreaks near the nursery.

TABLE 20.—*Formulas for insecticides and fungicides, after Potts and Waterman (1952)*

Formula No.	Ingredients	Water	Sticker or spreading agent
	INSECTICIDES	*Gallons*	
1	Lead arsenate 2 to 5 (av. 4) lb.	100	1 pt. of fish oil.
2	Derris or cube powder 4% rotenone) 2–8 lb.	100	½ gal. fish oil.
3	Nicotine sulfate (40% nicotine) 1 pint.	100	3 lb. solid soap or 6 lb. liquid soap.
4	Pyrethrum powder (0.8 to 1% pyrethrins) 1 lb.	100	Do.
5	Emulsifiable pyrethrum extract (1% pyrethrins) 1 pint.	100	None.
6	Derris or cube powder (4% rotenone) 1.5 lb.	100	3 lb. solid soap or 6 lb. liquid soap.
7	Oil emulsion (75% oil) 4 gal.	96	None.
8	Miscible oil (90% oil) 5 gal.	95	Do.
9	Miscible white oils 1 gal...	100	Do.
10	Lime sulfur (10 gal. liquid or 40 lb. dry).	90	Do.
11	Parathion 1 lb..........	100	Do.
11a	Tetraethyl pyrophosphate (40% emulsifiable) ½ pt.	100	Do.
12	Aramite 15 W. Neotran, or Dimite, 2 lb.	100	Do.
13	DDT (emulsifiable, 25% DDT) 1 qt.	100	Do.
13a	DDT (50% DDT wettable powder) 1 lb.	100	Do.
	FUNGICIDES		
14	Lime sulfur (2.5 gal. liquid or 6–8 lb. dry).	100	None.
15	Bordeaux-copper sulfate 8 lb., hydrated lime 10 lb.	100	Calcium caseinate 2 lb.
16	Bordeaux mixture powder 16 lb.	100	Do.
17	Wettable sulfurs..........	(1)	According to directions on container.
18	Sulfur dust [2]............	0	None.
19	Puratized agricultural spray 1 to 1.5 pts.	100	Do.
20	Ferbam 1.5–2 lb..........	100	Do.
21	Ferbam ½ lb., wettable sulfur 3 lb.	100	Do.
22	Elgetol 1 gal.............	100	Do.

[1] According to directions on container.

[2] For control of chewing insects, 2 pounds of lead arsenate or 1 pound of 50 percent DDT powder can be added per 10 pounds of sulfur.

TABLE 21.—*Concentrated-spray formulations for use in mist blowers, aircraft, and hand atomizers, after Potts (1952)*

Formula No.	Ingredients	Quantity to make: 1 gal.	Quantity to make: 100 gal.	Gallons to apply: Per acre	Gallons to apply: Per 60-ft. tree	Percent of toxicant
1	DDT	⅖ lb	40 lb	2¼	½	5
	Kerosene	1 gal	99 gal			
2	DDT, technical	½ lb	50 lb	2	½	6
	Xylene	1¼ pt	15⅔ gal			
	Kerosene	6¾ pt	81⅜ gal			
3	DDT, technical	½ lb	50 lb	2	½	6
	Xylene	1¼ pt	15⅔ gal			
	Triton X–100	¾ oz	⅝ gal			
	Water	6½ pt	82 gal			
4	DDT, 50% wettable powder	1 lb	100 gal	2	½	6
	Water	1 gal	97 gal			
5	Benzene hexachloride, emulsifiable 20% gamma isomer.	4 oz	3⅛ gal	4	1	.67
	Water	7¾ pt	97 gal			
6	Chlordane, 50% emulsifiable	1 pt	12½ gal	2	½	6
	Kerosene or water	7 pt	87½ gal			
7	Chlordane, 50% wettable powder	1 lb	100 lb	2	½	6
	Water	1 gal	97 gal			
8	Nicotine sulfate	8 oz	6¼ gal	4	1	2.5
	Water	7½ pt	93¾ gal			
9	Rotenone, 5% emulsifiable extract	1 pt	12½ gal	5	1½	.6
	Water	7 pt	87½ gal			
10	Rotenone, 5% powder	1 lb	100 lb	5	1¼	.6
	Water	7½ pt	94 gal			
	Mineral oil (50 to 90 sec. Saybolt)	3 oz	2½ gal			
11	Pyrethrum extract, 1% emulsifiable	1 pt	12½ gal	4	1	.125
	Water or kerosene	7 pt	87½ gal			
12	Lead arsenate	2 lb	200 lb	6	1½	21
	Water	7⅕ pt	90 gal			
	Mineral oil (50 to 90 sec. Saybolt)	⅖ pt	5 gal			
13	Refined white mineral oil (45 to 75 sec. Saybolt)	1 gal	100 gal	6	1½	100
14	Refined white miscible mineral oil (50 to 100 sec. Saybolt).	1 qt	26 gal	15	3¾	25
	Water	3 qt	74 gal			
15	DN–111	8 oz	50 lb	6	1½	6
	Water	1 gal	98½ gal			
16	Aramite 15W	1 lb	100 lb	6	1½	2
	Water	7⅗ pt	95 gal			
	Soybean oil or linseed oil	⅕ pt	2½ gal			
17	Liquid lime sulfur	1 gal	100 gal	15	3¾	100

MOUSE BAITS

Zinc Phosphide Formula

The zinc phosphide formula (Garlough and Spencer 1944) is as follows:

Steamed rolled oats	98 pounds.
Zinc phosphide	1 pound.
Amber petroleum jelly	10 ounces.
Mineral oil	10 ounces.

The mineral oil and petroleum jelly are warmed together until they are fluid, but not hot. Zinc phosphide is added to the mixture and stirred vigorously. This material is then poured over the oats and mixed thoroughly. Zinc phosphide baits are generally effective for about 3 weeks after preparation.

Strychnine Alkaloid Formula

Because of its bitter taste, strychnine alkaloid sometimes is not as readily accepted by certain mice. The formula is as follows:

Steamed rolled oats	12 pounds.
Powdered strychnine alkaloid	1 ounce.
Baking soda	1 ounce.
Gloss starch	¾ ounce.
Water	1 pint.
Heavy corn sirup	¼ pint.
Glycerine or petrolatum	1 tablespoonful.

The starch is mixed with one-fourth teacup of cold water, stirred into three-fourths pint of boiling water, and cooled until it forms a thin paste. Strychnine is mixed with the baking soda, added to the starch paste, and stirred until free of lumps. The corn sirup and glycerine or petrolatum are then added. The mixture is poured over the oats and allowed to dry before sacking.

SOURCES OF INFORMATION ON NURSERY PROBLEMS

Nurserymen who have problems with nursery insects or diseases can obtain advice on identification and control by writing to their State agricultural college or their State nursery inspector; the latter is invariably a trained pathologist or entomologist. The inspector may also send out releases on new quarantine regulations affecting the nursery industry. Another source of information on nursery disease and insect problems is the Division of Forest Protection Research, Forest Service, U.S. Department of Agriculture, Washington, D.C., 20250.

Advice on control of mammals and birds can be obtained from the Fish and Wildlife Service, U.S. Department of the Interior, Washington, D.C., 20240, or from the conservation departments of the respective States.

Nurserymen who plan interstate shipments of stock should become familiar with Federal and State regulations which may affect their shipments. This information can be obtained from the Plant Quarantine Division, Agricultural Research Service, U.S. Department of Agriculture, Washington, D.C., 20250.

Problems on nursery soils can be referred to the soils departments of State colleges and universities.

SOURCES OF INFORMATION ON NURSERY MACHINERY, EQUIPMENT, AND CHEMICALS

The nursery industry as much as possible uses equipment and products of standard manufacture. A list of manufacturers of nursery machinery, equipment, and chemicals can be obtained from the Forest Service, U.S. Department of Agriculture, Washington, D.C., 20250.

Blueprints of specialized equipment, either assembled from manufacturers' parts or to be built by the nurseryman, can be obtained from one of the several regional offices of the U.S. Forest Service.

The North Central Region of the U.S. Forest Service (consisting of North Dakota, Minnesota, Wisconsin, Michigan, Iowa, Missouri, Illinois, Indiana, and Ohio) has blueprints of certain items of special equipment (tree lifters, hand trenchers, root pruners, tree balers, etc.) or of buildings (central warehouses, cold storage sheds, cone storage sheds, and extractories, etc.). Nurserymen can obtain these blueprints at cost by writing to the Regional Forester, U.S. Forest Service, Milwaukee, Wis.

In the Rocky Mountain Region (consisting of South Dakota, Nebraska, Kansas, Colorado, and a major portion of Wyoming) similar blueprints can be obtained by writing to the Regional Forester, U.S. Forest Service, Denver, Colo.

Requests of nurserymen in Oklahoma and Texas should be addressed to the Regional Forester, U.S. Forest Service, Atlanta, Ga.

Nurserymen in Montana can obtain blueprints from the Regional Forester, U.S. Forest Service, Missoula, Mont.

REQUIREMENTS AND PROCEDURES FOR NURSERY STOCK INSPECTION IN THE PLAINS STATES

Each State has laws requiring inspection of trees before they can be sold and removed from the nursery premises. In brief, these laws provide for an annual inspection of the nursery by the State nursery inspector or his representative, define the fees to be charged, and provide for the issuance of a certificate of inspection. The law names certain species on which there is a quarantine regarding shipment into the State; defines the power of the nursery inspector to recommend and enforce destruction of certain pest-infested stock or to enforce its treatment with appropriate insecticides or fungicides; provides for tagging State shipments of nursery stock and wildings; and provides for penalties for violations of quarantine and other aspects of nursery regulations.

Individuals in any of the Plains States contemplating growing or selling nursery stock can obtain detailed information on current laws affecting the business by writing to one of the following agencies:

1. In Colorado: State Department of Agriculture, 3130 Zuni Street, Denver, Colo.
2. In Kansas (for portion of State north of Smoky Hill and Kansas Rivers): Nursery Inspector, Department of Entomology, Kansas State College, Manhattan, Kans.
3. In Kansas (for portion of State south of Smoky Hill and Kansas Rivers): Nursery Inspector, Department of Entomology, University of Kansas, Lawrence, Kans.
4. In Montana: State Nursery Inspector, East Broadway, Missoula, Mont.
5. In Nebraska: State Entomologist and Nursery Inspector, Bureau of Plant Industry, State Capitol Building, Lincoln, Nebr.
6. In North Dakota: State Nursery Inspector, North Dakota State University, Fargo, N. Dak.
7. In Oklahoma: Nursery Inspector, Entomology Division, State Department of Agriculture, Oklahoma City 5, Okla.
8. In South Dakota: State Nursery Inspector, State Department of Agriculture, Pierre, S. Dak.
9. In Texas: State Entomologist, 308 Capitol Building, Austin, Tex.
10. In Wyoming: State Entomologist, 308 Capitol Building, Cheyenne, Wyo.

Plant quarantine regulations that are in force on a national basis by the U.S. Department of Agriculture are available from the Plant Quarantine Division, Agricultural Research Service, U.S. Department of Agriculture, Washington, D.C., 20250.

U.S. DEPARTMENT OF AGRICULTURE FOREST TREE SEED POLICY (1939)

The U.S. Department of Agriculture has adopted a forest tree seed policy regarding seeds of trees and shrubs to be used in reforestation, shelterbelt, and erosion control planting. It provides guidance for its various conservation agencies engaged in such work. The policy is given below:

Recognizing that trees and shrubs, in common with other food and fiber plants, vary in branch habit, rate of growth, strength and stiffness of wood, resistance to cold, drought, insect attack, and disease, and in other attributes which influence their usefulness and local adaptation for forest, shelterbelt, and erosion-control use, and that such differences are largely of a genetic nature, it shall be the policy of the United States Department of Agriculture insofar as practicable to require for all forest, shelterbelt, and erosion-control plantings, stocks propagated from segregated strains or individual clones of proven superiority for the particular locality or objective concerned.

Furthermore, since the above attributes are associated in part with the climate and to some extent with other factors of environment of the locality of origin, it shall be the policy of the U.S. Department of Agriculture:

1. To use only seed of known locality of origin and nursery stock grown from such seed.
2. To require from the vendor adequate evidence verifying place and year of origin for all lots of seed or nursery stock purchased, such as bills of lading, receipts for payments to collectors, or other evidence indicating that the seed or stock offered is of the source represented. When purchases are made from farmers or other collectors known to operate only locally, a statement capable of verification will be required as needed for proof of origin.
3. To require an accurate record of the origin of all lots of seed and nursery stock used in forest, shelterbelt, and erosion-control planting, such records to include the following minimum standard requirements to be furnished with each shipment:
   (1) Lot number.
   (2) Year of seed crop.
   (3) Species.
   (4) Seed origin: State—County—Locality—Range of elevation.
   (5) Proof of origin.
4. To use local seed from natural stands whenever available unless it has been demonstrated that seed from another specific source produces desirable plants for the locality and uses involved. Local seed means seed from an area subject to similar climatic influences and may usually be considered as that collected within 100 miles of the planting site and differing from it in elevation by less than 1,000 feet.
5. When local seed is not available, to use seed from a region having as nearly as possible the same length of growing season, the same mean temperature of the growing season, the same frequencies of summer droughts, with other similar environment so far as possible, and the same latitude.
6. To continue experimentation with indigenous and exotic species, races, and clones to determine their possible usefulness, and to delimit as early as practicable climatic zones within which seed or planting stock of species and their strains may be safely used for forest, shelterbelt, and erosion-control.
7. To urge that States, counties, cities, corporations, other organizations, and individuals producing and planting trees for forest, shelterbelt, and erosion-control purposes, the expense of which is borne wholly or in part by the Federal Government, adhere to the policy herein outlined.

WHERE TO PURCHASE SEED

A partial list of tree-seed dealers in the United States and a few foreign countries can be obtained by writing to the Forest Service, U.S. Department of Agriculture, Washington, D.C., 20250.

A list that includes tree-seed dealers in the Plains States and dealers who handle seed native to the Plains States can be obtained from the Rocky Mountain Forest and Range Experiment Station, Colorado State University, Fort Collins, Colo.; and the Lake States Forest Experiment Station, St. Paul Campus, University of Minnesota, St. Paul 1, Minn.

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